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REPORT ON THE WATER-POWER

OF THE

REGION TRIBUTARY TO LONG ISLAND SOUND,

BY

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LETTER OF TRANSMITTAL.

BOSTON, MASS., *July* 9, 1883.

Professor W. P. TROWBRIDGE,

Columbia College, New York city.

SIR: I have the honor to submit a report upon the water-power of the region tributary to Long Island sound, based upon investigations carried on, under your direction, mainly in the summer and autumn of 1882. The results presented rest largely upon personal observation, but yet more upon interviews with manufacturers, civil engineers, and other persons having definite knowledge of the streams examined. Much has also been drawn from printed reports, and information has otherwise been derived from a variety of sources. With the limited time at my disposal it was out of the question to make a thorough examination of the numerous streams in this section, closely lined as many of them are with manufacturing sites, and some of the remoter districts had to be overlooked altogether. Nevertheless, enough has perhaps been learned to fulfill the general design of the work, in so far as it is included under the following headings: First, to furnish reliable information upon the topography, resources, and other physical conditions affecting the value of the principal streams for water-power; second, to give such description of existing improvements on the streams as might be of general interest or of use in planning future works; third, and especially, to present such data as it was practicable to obtain bearing upon the opportunities for further development of power. In this connection estimates of available power have been prepared for important sites, in accordance with principles fully explained elsewhere and uniformly followed in the reports committed to my care. Courtesy and aid were almost invariably received from those consulted during the work, and are gratefully acknowledged.

Very respectfully,

DWIGHT PORTER,

Special Agent.

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METHOD EMPLOYED IN ESTIMATING THE FLOW OF STREAMS.

It will be admitted by all that the only satisfactory mode of determining the volume of a stream is by careful measurements; and that, in order that such measurements shall truthfully show its character and capacity as regards flow, they must be continued regularly for a series of years. There are a very few rivers in the United States, such as the Connecticut, Sudbury, and Croton, with some others, that have been gauged in this manner; but the great majority have not been gauged at all, and even where measurements have been made there have usually been but one or two for a stream, and these have often been rudely carried out, and without recording very definitely the accompanying stage of water.

Under these circumstances it may seem rash to attempt any extended system of estimates. I have chosen to do so, however, and mainly for the following reasons: One of the great objects of this whole work has been to show, so far as possible, what opportunities exist for the development of new water-powers, and the further utilization of old ones. A natural and leading question concerning any privilege described would be as to the available power, and it is a question to which an answer only approximately correct is much better than none at all. A mere description of a stream stating that it is a certain number of feet wide and a certain number deep, that it has a swift or a sluggish current, and that it is well or poorly sustained in the dry season, conveys but a meager and indefinite idea as to its real capacity. Again, very erroneous views are frequently held and given out as to the power to be obtained at certain points. Not once only, but many times, it has been represented to me, with half honesty, that some privilege would carry "more machinery than is found at Lowell", or "all the machinery that could be placed upon it", while it was evident that the power was really quite limited. What is vaguely called the "average stage" of a stream is sometimes used as the basis for calculating its power, though it is manifestly an unfair basis. Although I recognize that the results of my estimates are liable to wide errors, and although I wish here to disclaim for them a pretension of accuracy, yet, in view of the facts I have stated, I think they may have a value in roughly indicating the available power of the various streams. I have endeavored to form them with care and discrimination; to obtain the best data possible; to compare the streams with each other; to adjust the results to actual measurements, where those have been made, rather than trust entirely to theory; and, especially, to place them under, rather than over, the truth.

These estimates will generally be found given for the following stages of flow:

1. *Low water of an ordinarily dry year.*
2. *Low water of an average year.*
3. *Available ten months in an average year.*

In using the term low water as above, I make exception of the abnormally low stage which a stream will sometimes reach, and maintain for some hours, or even a day or two, and which is due to the temporary shutting down at points above to permit mill-ponds to fill.

By an ordinarily dry year, I mean such an one as is likely to occur in the course of five or ten years. At longer intervals, ranging from ten to fifty years, remarkable droughts may occur, when a stream will sink still lower and reach its minimum, but such an occurrence is so exceptional that it need not here be considered.

Making the same exception as before for abnormally low flow, low water of an average year would, if gaugings were at hand, be determined as the average of the lowest gaugings of each of a series of years.

The third estimate is for the volume to be relied upon ten months in the average of years. Those ten months need not be consecutive; they express the sum total of the time during which the volume will be above a certain point, and include the period of high water, in which more or less hinderance, and even stoppage, are liable from backwater. It is very seldom that an important privilege is developed to a degree that can be realized only a few months in the year; but it is common to introduce wheels of a capacity for which the supply of water will suffice only nine or ten months, and it seems fitting that a corresponding estimate should be made.

In all cases, unless otherwise stated, the volume of a stream as given by me must be regarded as the average flow for twenty-four hours. By storage at dams during the night, and use of power in the day-time only, the flow can be concentrated and more than the average discharge realized during the working hours. But I have few data as to the extent of pondage that could be obtained; and the effects of storage, in varying amounts and at different points along a stream, are so intermingled that I think it impracticable to attempt estimates in which that item shall be taken into account. The calculated horse-powers are gross, or theoretical; from 60 to 80 per cent. of their amount will be yielded by good turbine-wheels.

The method employed by me in constructing my estimates involves two general assumptions:

1. A certain proportion of the mean annual rainfall as carried off, in the average of years, by each stream.
2. A certain distribution of that drainage through the year.

Both the assumed proportion and its distribution vary with the stream; the general reasons which act to change these conditions, such as topography, character of rainfall, lakes, forests, and other causes, are so well known, and have been so often stated, that I shall not rehearse them here. With regard to the first assumption, it may be said, in brief, that a large proportional discharge will be promoted by a prompt and thorough drainage of the rainfall into the water-courses; and that, generally speaking, those causes which are opposed to such a drainage will tend to produce a lower proportional discharge. The two qualities of promptness and thoroughness do not, however, always occur in the same degree, but vary widely with the surface and other conditions, and each may act to disguise, and even to overcome, an effect of the other: For example, other things remaining the same, from a steep, rocky district, with a scanty covering of soil, and devoid of forests, the introduction of the latter might result in a smaller annual drainage; but their introduction upon a flat region might increase the annual drainage by sheltering the surface of the ground and so diminishing evaporation; in other words, while in the latter case lessening the promptness of drainage, they might, to a much greater extent, increase its completeness.

In assuming the proportion of rainfall discharged by the streams, I have been guided by such published data as I was able to find. They are as follows:

A.—Connecticut river, at Hartford. For the eight years, 1871–'78, the discharge of this river was observed daily, under the direction of Mr. Theodore G. Ellis, civil engineer. The observations were made for the government, in the interests of navigation. The daily record for the years 1871–'77, both inclusive, is contained in *Ex. Doc. No.* 101, *House of Rep.*, *45th Congress*, *2d session*. *House Ex. Doc. No.* 42, *46th Congress*, *2d session*, contains the daily record for 1878, and also a summary of the discharge by months for the whole eight years. The drainage area above Hartford, as given by Mr. Clemens Herschel, is 10,234 square miles (see *Transactions Amer. Soc. Civ. Engrs.*, Vol. VII, No. clxviii). From the Smithsonian rainfall records I find the average rainfall over this section to be approximately 42.7 inches. Of this rainfall a mean annual percentage of 62.8 was discharged by the river; in the year of maximum discharge the percentage of the mean annual rainfall was 72.2, while in the minimum year it was 51.8. The area drained by the Connecticut is hilly and mountainous, the valleys being more or less cultivated, and the hills wooded and pasture land.

B.—Sudbury river, Massachusetts. In a paper by Mr. Alphonse Fteley (see *Transactions Amer. Soc. Civ. Engrs.*, Vol. X, No. ccxxiv) are given the results of a very careful series of gaugings of this river, extended through the six years 1875–'80, from which it appears that of a mean annual rainfall during that period of 46.1 inches, an average of 47.56 per cent. was collected by the stream.

Comparing the amount collected in any one year with the rainfall in the same year, the maximum percentage was 57.90 and the minimum 32.71.

Comparing the amount collected in any one year with the mean rainfall for the entire six years, the maximum percentage was 66.13 and the minimum 27.09. The drainage area included in these observations was 78 square miles, described as one-sixth to one-eighth wooded, and the balance farming land.

C.—See *Transactions Amer. Soc. Civ. Engrs.*, Vol. III, No. lxxxvii, *Notes on the Flow of the West Branch of the Croton River*—J. James R. Croes. As a mean from observations for 49½ months, it appears that the annual rainfall during the time, upon the basin of the West branch of the Croton river, was 50 inches, of which an average of 62.92 per cent. was discharged by the stream. The drainage area was 20.37 square miles. Regarding the surface features, Mr. Croes remarks:

> The surface of this water-shed is very broken and undulating, the hill-sides are steep and rocky, a large proportion of the area is covered with timber, and of the cleared portion the greater part is kept in grass, very little being cultivated. The rock, which lies near the surface over most of the area, is a very compact gneiss.

In the same paper is given the proportional discharge from the entire water-shed of the Croton river, from which the supply of New York city is drawn. "This water-shed includes that of the West branch, but is sixteen times as great, comprising 335 square miles. The proportion of flat and cultivated land is much greater." The discharge was not determined with as great accuracy as in the case of the West branch, but showed as the average of six years (1864–'69) a rainfall of 49.79 inches, of which 50.5 per cent. was carried off by the stream.

D.—In the report for the quarter ending June 30, 1879, of the Department of Public Works, New York city, is given the average daily flow of the Croton river at Croton dam for the thirteen years 1866–'78.

The drainage area is here stated as 339 square miles. The average annual rainfall during the period was 46.64 inches, of which the mean drainage by the stream was 56.5 per cent.

Comparing the drainage in any one year with the rainfall in the same year, the maximum ratio was 0.74, and the minimum 0.45.

Comparing the drainage in any one year with the mean rainfall for the whole thirteen years, the maximum ratio was 0.80, and the minimum 0.41.

E.—In a report by Captain Charles J. Allen, corps of engineers, U. S. Army, on the subject of reservoirs at the sources of the Mississippi (*Senate Ex. Doc. No.* 48, *46th Congress, 3d session*), there is given a table, copied from a report of the Boston water-board, showing the rainfall, rainfall collected, and percentage of rainfall collected, in inches, at Cochituate reservoir, during all but two years of the period 1852–'79.

The average rainfall was 49.59 inches, and the average percentage collected, 46.

Comparing the amount collected in any one year with the rainfall of that year, the greatest percentage was 78, and the least 25.

Comparing the amount collected in any one year with the mean annual rainfall, the greatest percentage was 94, and the least 30.

F.—In his report on the *Water-Power of Maine* (page 53), Mr. Walter Wells assumes 40 per cent. of the 42 inches annual rainfall of the state as passing off in the streams. He describes the state as, in general, moderately hilly, with a shallow soil, underlaid by hard and impervious rock. The northern slope of the state is comparatively uniform in elevation, and contains extensive swamps; the southern slope has a broken surface and a pretty uniform descent toward the sea. About one-fifth the surface of the state is more or less mountainous, and two-thirds is covered with forest.

G.—In a report made March 6, 1879, to the Newark aqueduct board, by Messrs. J. J. R. Croes and George W. Howell, on the subject of additional water-supply, the average annual yield of the Passaic, with a drainage area of 900 square miles, was estimated at 26.75 inches on that area, with a rainfall of 42.55 inches. The ratio of yield is 62.9 per cent. The rainfall on this basin varied, according to long continuous records, from 42.55 inches on the western boundary, to 46.40 and 53.80 inches, respectively, at two points near the eastern boundary. If we call the average for the basin 45 inches, then the ratio of assumed yield as above is 59.4 per cent. Regarding the surface drained, it is stated that—

Topographically, the water-shed above Paterson consists of a great central basin of about 200 square miles area, with a general elevation of 120 to 180 feet above tide-water, and surrounded on three sides by a broken and rocky hill country, extending generally for about 12 miles from the basin.

In the same report (page 37), the average yield of the Concord river is given as 18.62 inches, on a drainage area of 352 square miles. I find the annual rainfall on the basin to be 42.47 inches, from which it appears that 43.84 per cent. of this is carried off by the stream.

Again, in this report (page 37), the average annual yield of the Merrimack is stated to be 29.85 inches on a drainage area of 4,136 square miles. From the Smithsonian records I estimate the mean annual rainfall to be 46 inches above Lowell. The mean discharge of the Merrimack is, therefore, 64.9 per cent. of the rainfall.

H.—The report on a *Survey of the Waters of the Upper Hudson and Raquette Rivers*, made by Farrand N. Benedict, in 1874, assumes (page 22) that the annual rainfall on the plateau is 64.53 inches, and the drainage 45.42 inches, or 70.4 per cent. Mr. Benedict also remarks that William H. Talcott, civil engineer, in his report of 1839 upon the supply of water for the Genesee canal, concluded from experiments made in connection with a reservoir on Madison brook that "the drainage of Madison Brook valley during the whole year is 0.518 of the rainfall".

I.—Humphreys and Abbot's report on the Mississippi river contains approximate determinations of the ratios between rainfall and drainage for that river and its chief tributaries. The ratios as given vary from 15 to 90 per cent., and will be found in detail in the summary.

J.—Captain Allen, in his calculations for a reservoir system at the headwaters of the Mississippi, assumed for the sources of that river a mean annual rainfall of 25 inches, and for the available quantity actually finding its way into the streams, 0.7 of a foot, or 33.6 per cent. of the rainfall. (See Appendix S 8, page 1199, *Report Chief of Engineers*, 1879.)

K.—In the fall of 1880, Mr. Joseph P. Frizell, United States assistant engineer, in examinations carried on in connection with the Mississippi reservoir system, made a reconnaissance of Rock river (Wisconsin and Illinois) for suitable reservoir sites. In his report concerning Horicon reservoir, situated some 50 miles northwest of Milwaukee, and having a drainage area of 491 square miles, he assumes a rainfall—that of Milwaukee—of 35.33 inches, and that 40 per cent. of this finds its way into the reservoir. (See *Report Chief of Engineers*, 1881, page 1809.)

L.—On page 2400, *Report Chief of Engineers*, 1881, is a report by Mr. C. D. Ward, United States assistant engineer, on a water-supply for the proposed enlargement of the Wabash and Erie, and Miami and Erie canals. In estimating concerning the reservoir supply for those canals, Mr. Ward assumes an annual drainage of 10 inches, from a rainfall, at Bellefontaine, of 40.49 inches, or a percentage of 24.7. He states that—

Most of the gathering ground being rather flat, the rain running off slowly, giving time for a large amount of evaporation before reaching the streams, I have assumed 10 inches as the annual drainage.

M.—Humphreys and Abbot give the drainage area of the Missouri river as 518,000 square miles, the annual downfall of rain as 25,200,000,000,000 cubic feet, and the percentage drained off as 15 (=3,780,000,000,000 cubic feet). I was informed by Major Charles R. Suter, corps of engineers, U. S. Army, that for the year 1879 the total discharge of the Missouri was 2,335,143,946,400 cubic feet, and that it was not, probably, materially different in 1880, although at the time of his letter the calculations had not been made for that year. If we assume the mean annual rainfall at the same rate as assumed by Humphreys and Abbot, but for the more recently determined drainage area of, in round numbers, 528,000 square miles, the above discharge represents a percentage of only 9.1 of the average rainfall. Whether the year 1879 was an unusually dry one throughout the Missouri basin, I am unable to say; the following records of the signal service, at several scattered points, show how the year compared in rainfall in those localities with the average of years:

Rainfall in 1879 *at points in the Missouri basin, compared with the average rainfall at those points.*

[From Signal Service records.]

Locality.	Years of record.	Rainfall, 1879.	Rainfall, average.	Ratio of 1879 to average.
		Inches.	*Inches.*	
Saint Louis, Missouri	1871–'80	25.70	36.99	0.69
Leavenworth, Kansas	1872–'80	41.55	39.30	1.06
Omaha, Nebraska	1873–'80	30.31	33.13	0.91
North Platte, Nebraska	1875–'80	20.06	18.13	1.12
Yankton, Dakota	1874–'80	22.83	27.34	0.83
Denver, Colorado	1872–'80	10.86	14.64	0.74

N.—Clear creek is a mountain tributary of the South Platte river, in Colorado. It issues from the foot-hills of the Rocky mountains at Golden, above which point its drainage area is 436 square miles. As the result of a large number of measurements, extending at intervals through a period of over twenty years, and made by Captain E. L. Berthoud, of Golden, it appears that the annual drainage past that point is about 7.75 inches on the water-shed. Captain Berthoud estimates the average rainfall at 20.62 inches, of which 37.6 per cent. is, therefore, carried off by the stream.

A summary is herewith presented of the facts hitherto given concerning drainage:

Table showing observed and assumed ratios of drainage to rainfall in various parts of the United States.

Stream or locality.	Drainage area.	Mean annual rainfall.					Mean annual drainage.	Ratio of drainage to rainfall.	Remarks.
		Spring.	Summer.	Autumn.	Winter.	Year.			
	Sq. miles.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*		
A.—Connecticut river, at Hartford.	*a* 10,234	10.30	11.90	11.30	9.20	42.70	26.800	0.628	Drainage determined by measurements of discharge at Hartford for eight years. Country drained hilly and mountainous, rocky and wooded.
B.—Sudbury river, Massachusetts.	78	12.20	12.60	11.70	9.60	46.10	21.927	0.4756	Drainage determined by careful measurements of discharge for six years. Country drained *one-sixth to one-eighth* wooded, balance farming land.
C.—West branch of Croton river.	20.37	12.70	15.50	12.00	9.80	50.00	31.458	0.6292	Drainage determined by measurements of discharge for forty-nine and a half months. *Country drained broken and hilly, with steep* rocky slopes, timbered, and little cultivated.
Croton river	335–339	12.70	14.35	13.08	9.66	49.79	25.130	0.505	Drainage determined by measurements of discharge for six years; less accurate, however, than in case of West branch. Drainage area includes that of West branch, but proportion of flat and cultivated land is much greater.
D.—Croton river	335–339	11.90	13.43	12.25	9.06	46.64	26.352	0.565	Drainage determined by measurements of discharge for thirteen years.
E.—Cochituate reservoir	....	13.48	12.60	11.90	11.61	49.59	22.810	0.46	Based on observations for twenty-six years.
F.—Rivers of Maine	....	9.00	10.00	13.00	10.00	42.00	16.800	0.40	Assumed ratio of drainage in *Water-Power of Maine*. Surface of state moderately hilly, mountainous over about one-fifth, contains many lakes and swamps, is underlaid by impervious rock, and two-thirds covered with forest.
G.—Passaic river	900	10.93	11.93	11.42	8.27	42.55	26.750	0.629	Assumed ratio of drainage in estimating for water-supply. Rainfall assumed as given, though it varies on the drainage area from 42.55 to 46.46, and even 53.80 inches. Basin hilly and rocky.
Concord river	352	11.17	11.36	10.64	9.30	42.47	18.620	0.4384	Based on drainage as given by Croes and Howell.
Merrimack river	4,136	11.50	12.50	12.00	10.00	46.00	29.850	0.649	Do.
H.—New York plateau; upper waters of Hudson and Raquette rivers.	....	....	....	....	....	64.53	45.420	0.704	Ratio of drainage assumed by F. N. Benedict.
Madison brook, New York.	....	....	....	....	....	39.26 to 40.05	20.34 to 20.75	0.518	Conclusion as to ratio of drainage drawn by William H. Talcott, civil engineer, from experiments by John B. Jervis.
I.—Results for Mississippi river and tributaries, as given by Humphreys and Abbot: (*b*)									
Ohio river	214,000	10.80	12.00	9.30	9.30	....	10.057	0.24	Great variety of surface, from mountainous to rolling and flat, and from forest to open prairie.
Missouri river	518,000	7.10	6.50	4.40	2.70	....	3.141	0.15	Country mountainous and timbered at headwaters, but east of the Rocky mountains a rolling prairie without timber.
Upper Mississippi river	169,000	9.90	12.60	8.30	4.70	....	8.405	0.24	Heavy timber and many lakes.
Small tributaries	32,400	11.60	12.90	10.00	13.00	....	43.044	0.90	
Arkansas and White rivers.	189,000	6.80	11.60	7.20	4.00	....	4.555	0.15	Country mountainous at headwaters of Arkansas, thence eastward rolling prairie, till in Arkansas a more varied surface is encountered again, including some mountains and a large proportion of timber.
Red river	97,000	10.30	12.60	8.70	8.30	....	7.992	0.20	Large proportion of open prairie; lower basin timbered.
Yazoo river	13,850	11.10	10.20	9.00	15.80	....	41.952	0.90	
Saint Francis river	10,500	11.10	10.60	8.50	10.70	....	40.584	0.90	Basin heavily timbered; upper part hilly and broken; lower sunken and flat.
Entire Mississippi, exclusive of Red river.	1,147,000	....	....	....	....	....	7.318	0.25	
J.—Headwaters of Mississippi.	....	....	....	....	....	25.00	8.400	0.336	Ratio assumed by Captain Charles J. Allen, corps of engineers, in calculations for reservoir system.
K.—Horicon lake, Wisconsin.	491	9.72	11.27	8.59	5.75	35.33	14.130	0.40	Ratio assumed by Joseph P. Frizell, in calculations for reservoir.
L.—Proposed enlargement of Wabash and Erie, and Miami and Erie canals.	....	10.01	14.25	8.13	8.10	40.49	10.000	0.247	Ratio assumed by C. D. Ward, in calculations for reservoir supply. Country flat.
M.—Missouri river	*c* 528,000	....	....	....	....	....	*d* 1.904	....	Drainage for 1879 = 0.091× estimated mean annual rainfall.
N.—Clear creek, Colorado	436	....	....	....	....	20.62	7.750	0.376	Based on measurements by Captain E. L. Berthoud.

NOTE.—In some of the reports cited the rainfall is not given by seasons. In several such cases I have estimated the amounts from other rainfall records, and the figures must not, therefore, be depended on as strictly accurate.

a The drainage area taken in this article for the Connecticut river at Hartford is as given by Mr. Herschel, and is 80 square miles greater than my own measurement. The disagreement is too slight, however, to make any essential difference in the results obtained.

b In the case of the streams considered by Humphreys and Abbot I have stated the rainfall by seasons as given in their report. In estimating the yearly downfall, however, they adopted figures slightly different from the aggregates of the seasons as here given, and based upon the amounts shown by three different rain charts—the Army, Blodget's, and Delta Survey.

c Drainage area, in round numbers, by more recent measurement than that of Humphreys and Abbot.

d Year 1879 only.

The ratios of drainage which I have assumed in different sections range as follows:

Ratios of drainage to rainfall assumed in this work.

Section.	Mean annual rainfall on water-sheds considered. (a)	Assumed average annual drainage from water-sheds.	Assumed ratios of drainage to rainfall.
	Inches.	*Inches.*	
Region tributary to Long Island sound	40 –52	17½–27½	0.40–0.63
Hudson River basin	38 –40½	18 –24	0.45–0.60
Region tributary to lake Ontario			
Eastern Gulf slope	49 –54	15½–24½	0.30–0.50
Ohio River basin (portion lying in Ohio, Pennsylvania, and the northern part of West Virginia)			
Eastern Iowa slope	25½–42½	6½–12	0.25–0.30
Eastern Missouri slope	38½–39½	13½–14	0.35
Missouri River basin (portion draining to the main river below Yankton)	13 –41	2 –13½	0.10–0.35
Arkansas River basin (portion estimated upon is limited to southeastern Kansas and a part of the White River basin)	36½–39½	7½–13½	0.20–0.35
Red River basin (estimates confined to upper basin of Ouachita river)	50	12½	0.25

a The rainfalls here given are not necessarily the limits for the section considered, but rather refer to the data actually employed in estimates.

I shall now explain the second assumption made, viz, that of a certain proportional distribution of the drainage through the year. However uniform the volume of a stream may appear to the eye, it in reality hardly remains the same two days in succession, or, indeed, two hours in succession, but is subject to constant fluctuations, even though they be at times slight. The periods of high and low water are also of variable occurrence, and in a series of years may range through nearly every season. If, now, we take the flow of a stream by days for an entire year, and arrange it according to the days of least discharge, representing the average discharge of each day by a suitable ordinate, an approximation to some sort of a curve will result, which will illustrate the distribution of the flow through that year. If we are able to employ as the basis in constructing the curve the results of gaugings extending through a series of years, the characteristic of the stream as regards flow will be shown with great accuracy. My own experience in constructing such curves has been that, although from the records of a single year only a broken line may result, having no well-defined curvature, yet from the gaugings of a series of years a quite regular and beautiful curve will be obtained. This method of showing graphically the distribution of flow of any stream was, I think, first practically described and carried out by Mr. Clemens Herschel; (*a*) he arranged the results of gaugings by calendar months of least and greatest flow, but for my purposes I have preferred to arrange them by days where they were accessible in that form.

The forms which the curves, determined in this manner, may take, are infinite in variety, being due to all those diverse conditions, and their combinations, of climate and surface features, which affect the flow of streams. There are certain general principles, however, which may be observed regarding them. It is obvious that if the rate of discharge of a stream were to remain fixed and invariable throughout the year, its flow would be represented by a straight line parallel to the axis of abscissas. Any causes which act to throw it out of that condition of uniform flow will tend to produce a curve, and the greater the extremes between low and high water, the more will the curve depart from the position corresponding to an invariable volume.

We may construct the curves on three different bases:

1. With respect to the absolute rate of discharge in cubic feet per second per square mile of drainage area. The curves thus formed will show the striking contrast that exists between the streams of the Atlantic slope and those of the western prairie regions, as regards the yield per square mile. If the average high-water discharge of the Missouri river were at the same rate per square mile as that of the Connecticut, it would amount to over 6,000,000 cubic feet per second; and, similarly, the low-water discharge would be about 285,000 cubic feet per second.

2. Relatively to low water (average low water where that is known), taken as a basis of reference. In this manner the fluctuations of the streams will be brought out more prominently, and it will be noticed that the Arkansas, for instance, for the single year given, although its curve under the first case is flat, and shows only small variations in discharge per square mile, was really subject to a very great relative fluctuation of volume between low and high water.

3. We may construct the curves with reference to mean flow for a series of years, considering that as unity, or a basis of reference.

Such numerical data as I have been able to find, and upon which the curves shown are based, are given below. There are a few cases in which the gaugings have been carried through a series of years; I have also included some examples in which they were made for several months or a year only, and these may have some interest, though they are of much less practical value than the former.

a *Remarks on the Gauging of Streams*, made June 18, 1878, at the tenth annual convention of the American Society of Civil Engineers, by Clemens Herschel, civil engineer, member of the society. Mr. Herschel states that he received the first suggestion of the method from Mr. Joseph P. Davis, city engineer of Boston.

Table showing distribution of flow of streams through the year, in cubic feet per second per square mile of drainage area.

(*a*) ARRANGED ACCORDING TO DAYS OF LEAST DISCHARGE.

Stream.	Approximate drainage area.	Average (*a*) lowest day of the year, cubic feet per second per square mile.	30th.	60th.	90th.	120th.	150th.	180th.	210th.	240th.	270th.	300th.	330th.	360th.	Highest day.	Average flow for period here used, cubic feet per second per square mile.	Average flow for series of years, (*b*) cubic feet per second per square mile.
	Sq. miles.																
Connecticut, at Hartford (*c*)	10, 234	0. 540	0. 620	0. 690	0. 760	0. 870	1. 030	1. 250	1. 540	1. 970	2. 480	3. 250	4. 730	7. 720	11. 420	2. 021	*d*1. 973
Arkansas (*e*)	160, 000	0. 015	0. 022	0. 032	0. 056	0. 206	0. 269	0. 319	0. 364	0. 400	0. 425	0. 450	0. 469	0. 508	0. 538	0. 275	(?)0. 335
Mississippi, at Columbus (*f*)	930, 540	0. 140	0. 180	0. 260	0. 350	0. 460	0. 510	0. 570	0. 640	0. 730	0. 930	1. 140	1. 260	1. 490	1. 510	0. 602	0. 520
Mississippi, at Vicksburg and Natchez (*g*)	1, 154, 607	0. 200	0. 250	0. 340	0. 450	0. 620	0. 720	0. 760	0. 910	0. 990	1. 040	1. 060	1. 070	......	1. 080	0. 701	0. 539
Mississippi, at Carrollton (*h*)	1, 160, 000 to 1, 170, 000	0. 172	0. 219	0. 236	0. 253	0. 288	0. 412	0. 494	0. 618	0. 678	0. 735	0. 800	0. 910	0. 969	0. 989	0. 507	0. 539

a The average lowest day is employed where the records used cover more than one year.

b In some cases the results of this column are based upon longer records than were accessible for the detailed data necessary in making out the main portion of the table.

c Deduced from gaugings for the seven years 1872–'78.

d Eight years.

e Deduced from gaugings at Napoleon as given by Humphreys and Abbot; December 10, 1857, to December 6, 1858.

f From gaugings as given by Humphreys and Abbot; December 1, 1857, to November 30, 1858.

g From gaugings as given by Humphreys and Abbot; January 3 to December 15, 1858.

h From gaugings as given by Humphreys and Abbot; February 15, 1851, to February 18, 1852. Drainage area is exclusive of that of Red river.

(*b*) ARRANGED ACCORDING TO CALENDAR MONTHS OF LEAST DISCHARGE.

Stream.	Approximate drainage area.	Average (*a*) lowest month of the year, cubic feet per second per square mile.	2d.	3d.	4th.	5th.	6th.	7th.	8th.	9th.	10th.	11th.	12th.	Average flow for period here used, cubic feet per second per square mile.	Average flow for series of years, (*b*) cubic feet per second per square mile.
	Sq. miles.														
Sudbury (*c*)	78	0. 170	0. 250	0. 430	0. 600	0. 790	1. 120	1. 420	1. 850	2. 100	2. 630	3. 980	5. 890	1. 754	1. 615
West branch of Croton (*d*)	20	0. 390	0. 540	0. 760	0. 870	1. 120	1. 500	2. 380	2. 540	3. 140	4. 390	4. 680	6. 110	2. 317	2. 317
Croton (*e*)	339	0. 494	0. 839	0. 989	1. 069	1. 263	1. 607	2. 031	2. 269	2. 446	2. 607	3. 179	3. 532	1. 866	1. 940
Concord (*c*)	352	0. 344	0. 406	0. 450	0. 539	0. 671	0. 848	1. 104	1. 342	1. 695	2. 102	2. 640	4. 291	1. 371	1. 371
Passaic (*f*)	900	0. 530	0. 751	0. 971	1. 104	1. 325	1. 589	1. 898	2. 208	2. 561	3. 002	3. 532	4. 150	1. 969	1. 969
Merrimack (*c*)	4, 136	0. 680	0. 777	0. 936	1. 113	1. 342	1. 589	1. 872	2. 199	2. 675	3. 294	4. 088	5. 792	2. 197	2. 197
Missouri (*g*)	528, 000	0. 057	0. 065	0. 068	0. 074	0. 078	0. 090	0. 098	0. 146	0. 160	0. 204	0. 303	0. 341	0. 140	0. 231
Connecticut, at Hartford (*h*)	10, 234	0. 649	0. 690	0. 760	0. 885	1. 152	1. 397	1. 656	2. 102	2. 435	2. 830	4. 427	5. 270	1. 973	1. 973

a The average lowest month is employed where the records used cover more than one year.

b In some cases the results of this column are based upon longer records than were accessible for the detailed data necessary in making out the main portion of the table.

c Deduced from careful gaugings for the five years 1875–'79.

d From gaugings for the three following years: May, 1867, to April, 1868; January to December, 1870; January to December, 1871.

e Deduced from monthly average flow for a series of years, as given by Croes and Howell in report to Newark aqueduct board, 1879.

f Deduced from monthly average flow for a series of years, as estimated by Croes and Howell in report to Newark aqueduct board, 1879.

g From gaugings for the year 1879.

h From gaugings for the eight years, 1871–'78.

Flow as given in preceding table, arranged relatively to lowest day or month.

(*a*) BY DAYS OF LEAST DISCHARGE.

Stream.	Average lowest day (assumed as unity).	30th.	60th.	90th.	120th.	150th.	180th.	210th.	240th.	270th.	300th.	330th.	360th.	Highest day.
Connecticut	1.00	1.15	1.28	1.41	1.61	1.91	2.31	2.85	3.65	4.59	6.02	8.76	14.30	21.15
Arkansas (*a*)	1.00	1.49	2.16	3.82	14.03	18.28	21.68	24.74	27.21	28.91	30.61	31.88	34.56	36.56
Mississippi, at Columbus (*a*)	1.00	1.29	1.86	2.50	3.29	3.64	4.07	4.57	5.21	6.64	8.14	9.00	10.64	10.79
Mississippi, at Vicksburg and Natchez (*a*)	1.00	1.25	1.70	2.25	3.10	3.60	3.80	4.55	4.99	5.20	5.30	5.35	....	5.40
Mississippi, at Carrollton (*a*)	1.00	1.27	1.37	1.47	1.67	2.39	2.87	3.59	3.94	4.27	4.65	5.29	5.63	5.75

(*b*) BY MONTHS OF LEAST DISCHARGE.

Stream.	Average lowest month (assumed as unity).	2d.	3d.	4th.	5th.	6th.	7th.	8th.	9th.	10th.	11th.	12th.
Sudbury	1.00	1.47	2.53	3.53	4.65	6.59	8.35	10.88	12.35	15.47	24.59	34.65
West branch of Croton	1.00	1.38	1.95	2.28	2.87	3.85	6.10	6.51	8.05	11.26	12.00	15.67
Croton	1.00	1.70	2.00	2.16	2.56	3.25	4.11	4.59	4.95	5.40	6.44	7.15
Concord	1.00	1.18	1.31	1.57	1.95	2.47	3.21	3.90	4.93	6.11	7.70	12.47
Passaic	1.00	1.42	1.83	2.08	2.50	3.00	3.58	4.17	4.83	5.66	6.66	7.83
Merrimack	1.00	1.14	1.38	1.64	1.97	2.34	2.75	3.22	3.93	4.84	6.01	8.52
Missouri (*a*)	1.00	1.14	1.19	1.30	1.37	1.58	1.72	2.56	2.81	3.58	5.32	5.98
Connecticut	1.00	1.06	1.17	1.36	1.77	2.15	2.55	3.24	3.75	4.36	6.82	8.12

a Results based upon observations for a single year, as previously noticed.

Flow as given in table on preceding page, arranged relatively to average flow for a series of years.

(*a*) BY DAYS OF LEAST DISCHARGE.

Stream.	Average flow (assumed as unity).	Average lowest day.	30th.	60th.	90th.	120th.	150th.	180th.	210th.	240th.	270th.	300th.	330th.	360th.	Highest day.
Connecticut	1.00	0.27	0.31	0.35	0.39	0.44	0.52	0.63	0.78	1.00	1.26	1.65	2.40	3.91	5.79
Arkansas (*a*)	1.00	0.04	0.07	0.10	0.17	0.62	0.80	0.95	1.09	1.19	1.27	1.34	1.40	1.52	1.60
Mississippi, at Columbus (*a*)	1.00	0.27	0.35	0.50	0.67	0.88	0.98	1.10	1.23	1.40	1.79	2.19	2.42	2.87	2.90
Mississippi, at Vicksburg and Natchez (*a*)	1.00	0.37	0.46	0.63	0.83	1.15	1.33	1.41	1.69	1.84	1.93	1.97	1.99	....	2.00
Mississippi, at Carrollton (*a*)	1.00	0.32	0.41	0.44	0.47	0.53	0.76	0.92	1.15	1.26	1.36	1.48	1.69	1.80	1.83

(*b*) BY MONTHS OF LEAST DISCHARGE.

Stream.	Average flow (assumed as unity).	Average lowest month.	2d.	3d.	4th.	5th.	6th.	7th.	8th.	9th.	10th.	11th.	12th.
Sudbury	1.00	0.11	0.16	0.27	0.37	0.49	0.69	0.88	1.15	1.30	1.63	2.46	3.65
West branch of Croton	1.00	0.17	0.23	0.33	0.38	0.48	0.65	1.03	1.10	1.36	1.90	2.02	2.64
Croton	1.00	0.25	0.43	0.51	0.55	0.65	0.83	1.05	1.17	1.26	1.37	1.64	1.82
Concord	1.00	0.25	0.30	0.33	0.39	0.42	0.62	0.81	0.98	1.24	1.53	1.93	3.13
Passaic	1.00	0.27	0.38	0.49	0.56	0.67	0.81	0.96	1.12	1.30	1.52	1.79	2.11
Merrimack	1.00	0.31	0.35	0.43	0.51	0.61	0.72	0.81	1.00	1.22	1.50	1.86	2.64
Missouri (*a*)	1.00	0.25	0.28	0.29	0.32	0.34	0.39	0.42	0.63	0.69	0.88	1.31	1.48
Connecticut	1.00	0.33	0.35	0.39	0.45	0.58	0.71	0.84	1.07	1.23	1.43	2.24	2.67

a Results based upon observations for a single year, as previously noticed.

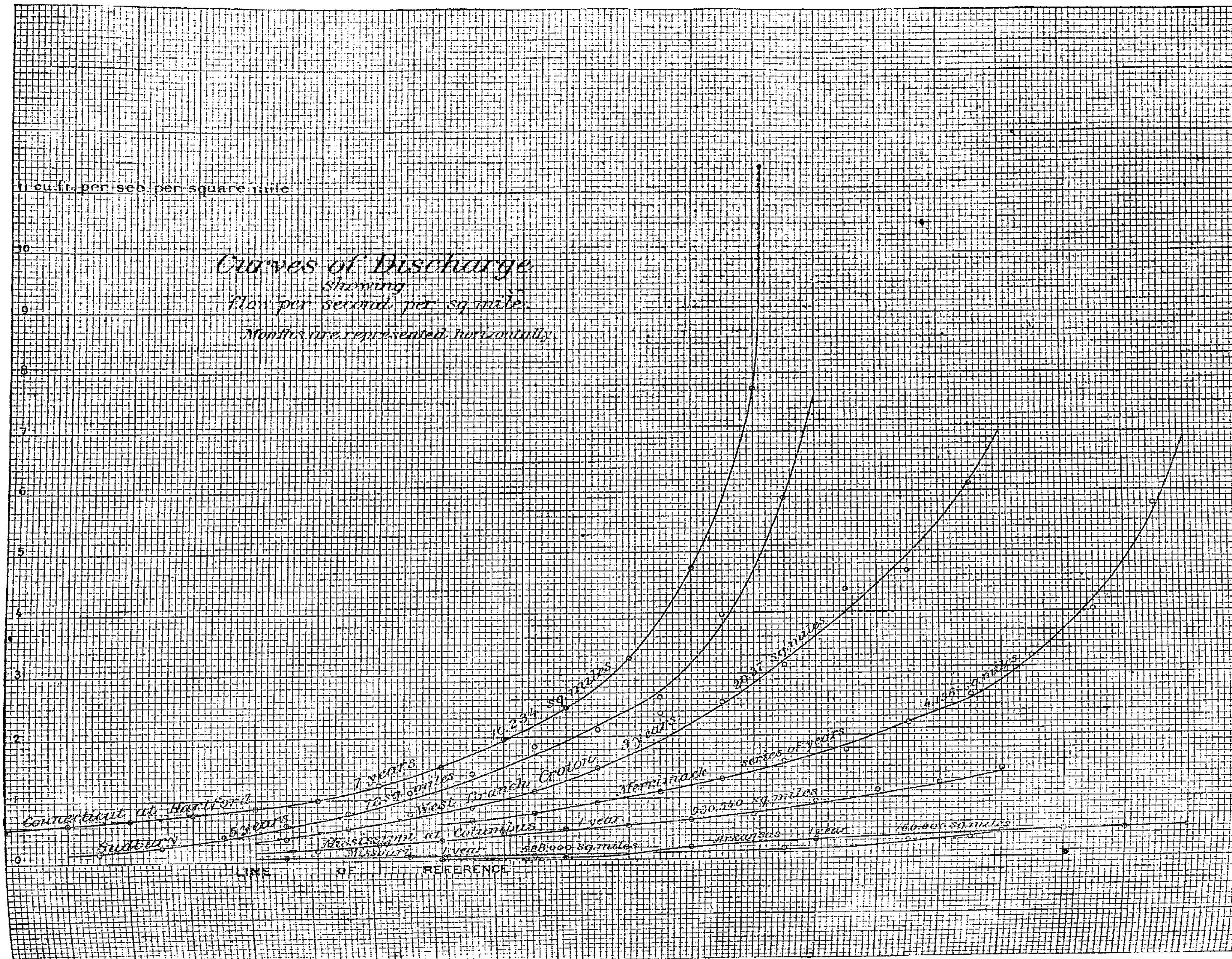

FIG. 1.—Curves of discharge.

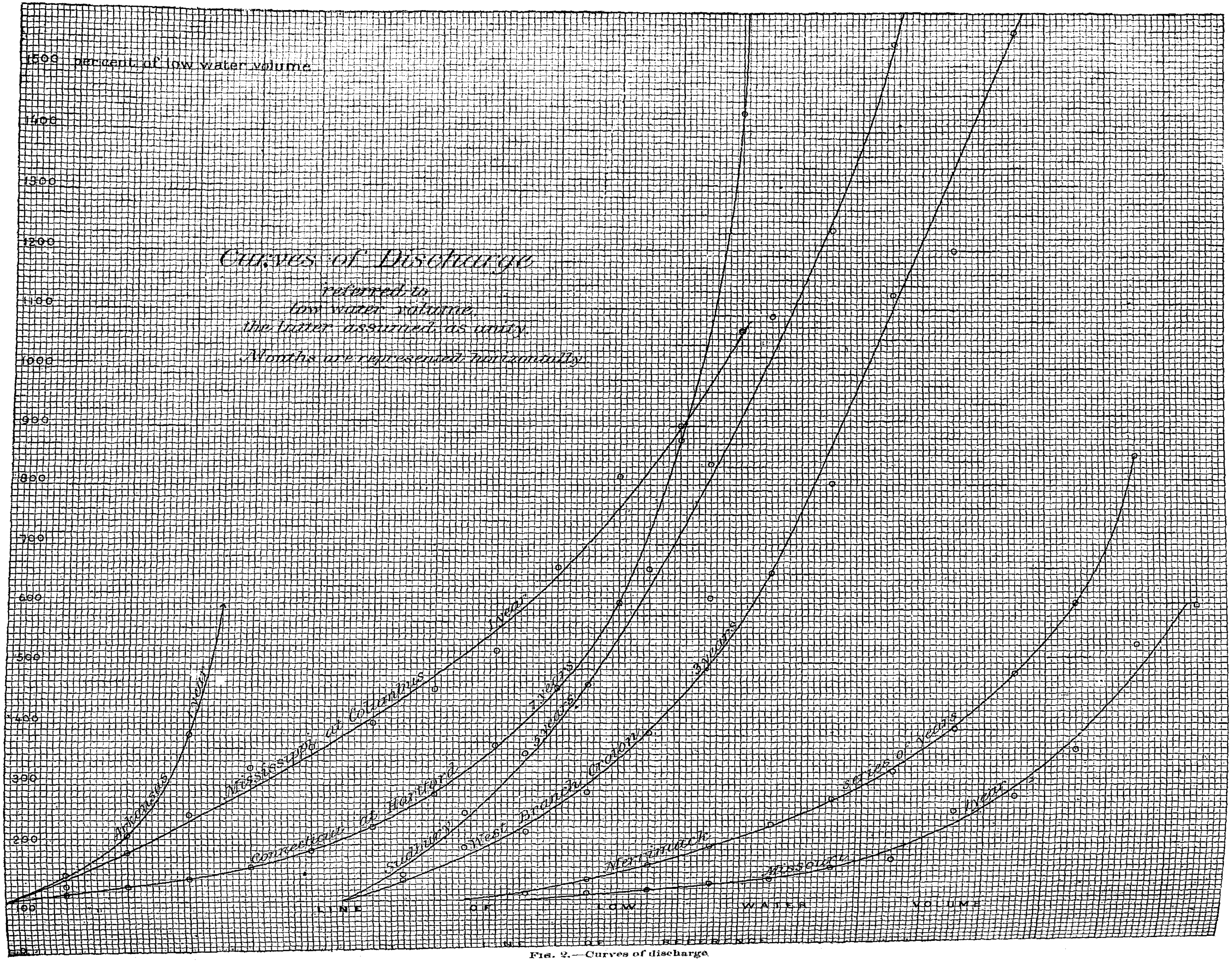

FIG. 2.—Curves of discharge

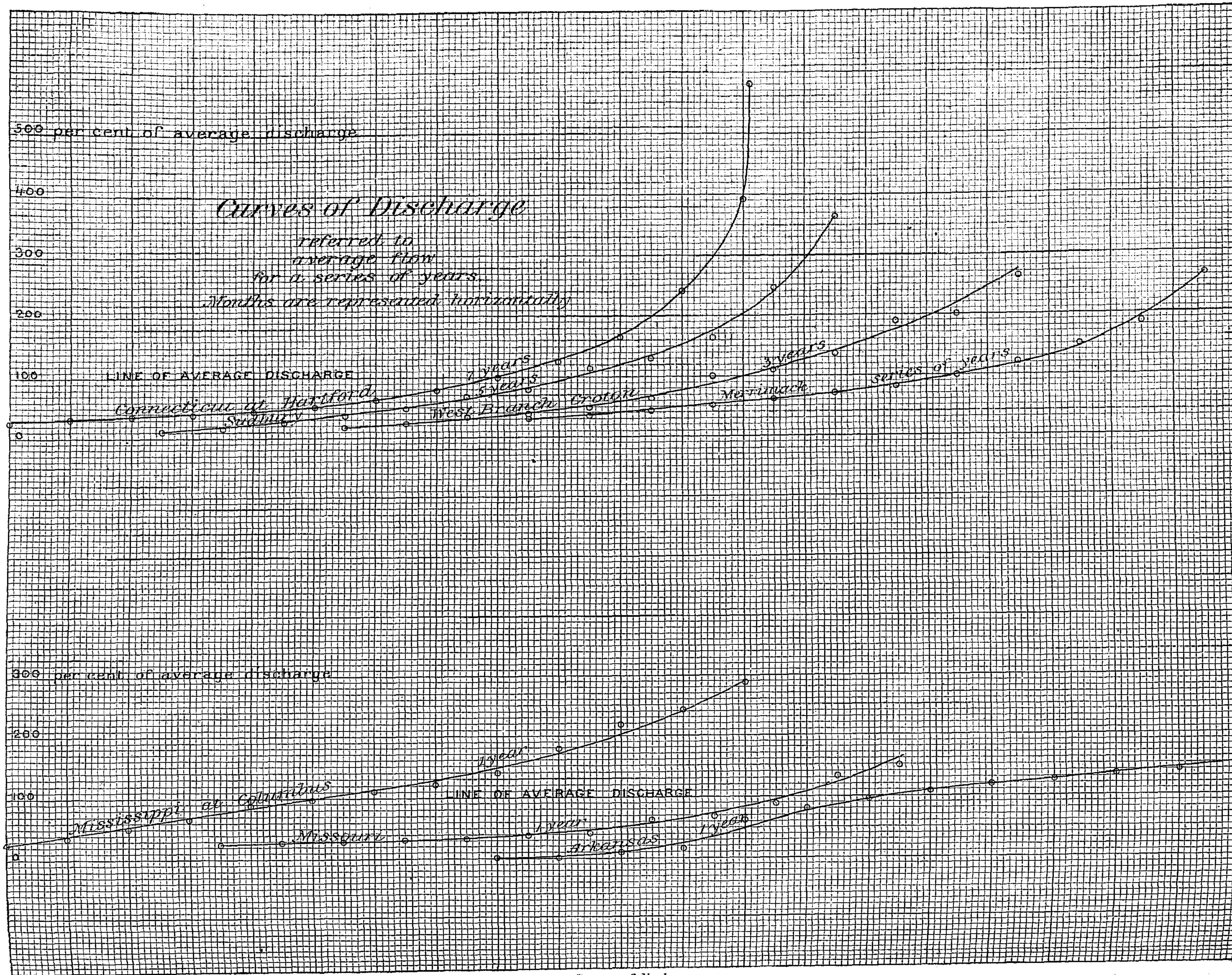

FIG. 3.—Curves of discharge.

In fixing upon the rate of discharge for low water of a dry year I have assumed a certain absolute figure per square mile of drainage area for each stream, in the selection of which I have been guided by the results of gaugings made either upon the stream considered, or upon some neighboring one. The ratio which exists between low water of a dry year and that of an average year, as determined by measurements, can be given in only a few cases, as follows:

Ratio between low water of dry and of average years.

Stream.	Approximate drainage area.	Low water of dry year, cubic feet per second per square mile.	Low water of average year, cubic feet per second per square mile.	Ratio dry to average year.	Remarks.
	Sq. miles.				
Connecticut, at Hartford	10,234	0.509	0.540	0.94	Obtained from records previously referred to, by comparing the gaugings of the lowest days in each of the years from 1872 to 1878. The extreme range for those gaugings was from about 0.51 to 0.59 cubic foot per second per square mile.
Do	....	0.598	0.649	0.92	Obtained from records for eight years, 1871–'78, by comparing the total discharge of the calendar months of least flow in each year. The extreme range for those totals was from about 0.60 to 0.715 cubic foot per second per square mile.
Sudbury	78	0.092	0.170	0.54	Obtained by comparing the total discharge of the calendar months of least flow in each of the five years 1875–'79. The extreme range for those totals was from 0.092 to 0.284 cubic foot per second per square mile.
West branch of Croton	20	0.084	0.390	0.22	Obtained by comparing the total discharge of the calendar months of least flow in each of the three years: May, 1867, to April, 1868; January to December, 1870, and January to December, 1871. The extreme range for those totals was from 0.084 to 0.736 cubic foot per second per square mile.
Croton	339	0.177	0.494	0.36	Obtained by comparing the monthly dry-season flow with the monthly average flow for a series of years, as given by Croes and Howell, in report to Newark aqueduct board.
Concord	352	0.221	0.344	0.64	Do.
Passaic (estimated)	900	0.177	0.530	0.33	Do.
Merrimack	4,136	0.601	0.680	0.88	Do.
Illinois	29,000	0.055	0.060	0.92	Obtained by comparing extreme low-water flow and ordinary low-water flow, as given by Major G. J. Lydecker, corps of engineers, U. S. Army.

THE REGION TRIBUTARY TO LONG ISLAND SOUND.

TOPOGRAPHY OF THE SURFACE AND GENERAL FEATURES OF THE STREAMS.

The section of country which will here be considered extends from the Thames basin, on the east, westerly to that of the Bronx, including both, and comprises an area of about 15,500 square miles. It stretches from 250 to 275 miles in a north-and-south direction, and has an extreme width of about 100 miles; it is confined chiefly to Connecticut, Massachusetts, Vermont, and New Hampshire, but also embraces small portions of Rhode Island, New York, and Canada.

The surface is nearly everywhere hilly, and is even, to a considerable extent, mountainous. The Norfolk hills in northwestern Connecticut, probably the most elevated land in that state, rise to elevations of over 1,400 feet. Graylock, the highest point of Saddle mountain, in Berkshire county, Massachusetts, situated slightly beyond the western border of the region I am describing, reaches a height of nearly 3,600 feet above tide-water. Mount Holyoke, in the same state, is nearly 1,000 feet high. To the northward, the peaks of the Green mountains, in Vermont, reach elevations of 2,500 to 4,300 feet above sea-level; and those of the White mountains, in New Hampshire, 4,000 to 6,000 feet and over.(*a*) The White mountains are stated to cover an area of 1,270 square miles, and in appearance are quite in contrast with the Green mountains, being more rugged and less fertile. The mountain ranges of western New England have a generally north-and-south direction, and to the southward, where the country is less elevated, the same trend is preserved by parallel lines of hills. The rocks which compose the mountains and otherwise crop out over the general surface of the country, are of the older formations, and are mainly comprised in granite, gneiss, mica-slate, mica-schist, and syenite. They are intersected by numerous dikes of trap, and an extensive ridge of that material runs in a northerly direction from New Haven, on the sound, across Connecticut and half-way across Massachusetts. As an exception to the general class of rocks mentioned above, is to be noted a belt of red sandstone, which also starts from the vicinity of New Haven, strikes northeasterly to the Connecticut River valley, and follows its course up to the northern boundary of Massachusetts.

Stretching down from the western slope of the Green mountains over the western portion of the region we are studying, and embracing the Taconic range in Massachusetts and a part of Connecticut, are outcropping limestone strata, which furnish valuable supplies of marble. Granite and gneiss of fine quality for architectural purposes are quarried at various points, and along the Housatonic valley are extensive deposits of hematite iron ore, which are worked, however, only to a small extent.

Along the course of the Connecticut, and in a much less degree along most of the other streams, are alluvial deposits, but the great and abounding surface material is almost everywhere drift. It covers the entire region from east to west and from north to south, its southern boundary running lengthwise of Long Island. Its constituents are here, as elsewhere, sand, clay, gravel, and bowlders. In the *Report on the Geology of Vermont* various bowlders are described weighing from 500 up to 3,500 tons each. Rocks and stones lie irregularly scattered over and beneath the surface, and many hill-sides are so thickly covered with them as to present a very barren and forbidding appearance. The drift covers even the higher portions of the Green mountains. As to the thickness which the deposit attains in some parts of New England, Dr. Hitchcock, in his *Report on the Geology of Massachusetts*, remarks that in that state it has been found at Palmer to the depth of 70 to 80 feet without reaching rock, and that in Plymouth and Barnstable, hills of it exist 300 feet in height. In other parts of the state he estimates the maximum thickness at 100 feet.

The soil varies greatly in fertility; the alluvial meadows along the Connecticut, Farmington, Lower Deerfield, and other rivers, are very productive, while the more elevated country is often stony and poor; and yet the conditions are, in other cases, not infrequently reversed, the hill-tops being rich farming land and the neighboring valleys of the smaller streams almost worthless. The country may be said, as a whole, to be well wooded; the

a Mount Washington has an altitude of 6,293 feet.

timber is largely of a young growth, and in southern New England is mostly found upon the hills, which, owing in many cases to their height and steepness, or the poorness of their soil, are reserved for woodland, the lower ground being devoted to agriculture. The leading varieties of timber are hemlock, fir, spruce, pine, oak, beech, sugar-maple, hickory, elm, butternut, basswood, birch, cedar, ash, and poplar. What forests remain are in the north, and it is there that the principal cutting of timber now goes on. The destruction there is just as thorough and apparently indiscriminate as it is stated to be in other portions of the United States, and the section along the upper course of the Connecticut river appears more bare than much that it drains toward its mouth.

Lakes constitute a noticeable and important surface feature. They are well distributed, being found quite generally throughout the region I am describing. In the Vermont geological report already referred to, Mr. Albert D. Hager gives a list of 67 lakes and ponds in that state varying from half a mile to 8 miles in length, and from half a mile to 2½ miles in width. In Appendix B of the report for 1873 of the Massachusetts State Board of Health a list prepared by Mr. H. F. Walling is given of all the lakes, ponds, and reservoirs in that state containing more than 10 acres. The total number of these is 1,206, with an aggregate area of about 93,000 acres, or, say, 145 square miles. Their distribution is as follows, by counties and according to size:

Number and size of lakes, ponds, and reservoirs in Massachusetts.

Size.	Number.	Size.	Number.
10 to 100 acres	976	700 to 800 acres	4
100 to 200 acres	135	800 to 900 acres	1
200 to 300 acres	42	1,000 to 2,000 acres	5
300 to 400 acres	26	Over 2,000 acres (2,007 and 2,220)	2
400 to 500 acres	6		
500 to 600 acres	5	Total number	1,206
600 to 700 acres	4		

Distribution.

County.	Area of lakes, ponds, and reservoirs.	County.	Area of lakes, ponds, and reservoirs.
	Acres.		*Acres.*
Berkshire	6,226	Bristol	7,961
Franklin	2,184	Plymouth	17,623
Hampshire	2,282	Barnstable	9,721
Hampden	4,148	Dukes	90
Worcester	25,007	Nantucket	33
Middlesex	8,743		
Essex	4,570	Total area	92,938
Norfolk	4,350		

As to the origin of the Vermont lakes, Mr. Hager says:

The position and extent of lakes, as well as mountains, are dependent, in a great measure, upon the geological character of the country in which they lie. Their origin is the result of three distinct causes, and hence lakes and ponds may properly be divided into three classes: First, those where the beds were formed at very remote periods, when the upheaval of the rock took place, and left deeply indented fissures; secondly, those that occupy deep, eroded valleys; and thirdly, those of more recent date, and not dependent upon a rock formation for their base or sides, but upon a deposit of clay or some other substance impervious to water, reposing upon a gravelly or hard-pan base. A limited examination has been made of the lakes and ponds, to determine the nature of their origin; and our conclusions are that much the larger proportion of lakes and ponds belong to the second class, and occupy eroded basins. The third class of ponds in Vermont is not of the antiquity of the first two classes, and such ponds are not dependent upon rock formations for their base and sides. They date back to the period of the drift for their origin, being found in drift formations, and doubtless rest upon a basin-shaped cavity lined with clay or some substance impervious to water. They are usually fed by deep-seated springs, and rarely have large visible outlets or inlets.

The following table will convey a general idea of the temperature and rainfall, during the different seasons of the year, over the region tributary to Long Island sound. It is necessarily faulty in one important respect, in that it is almost entirely confined to low altitudes, there being very few stations of more than 1,000 feet elevation where long-continued climatic observations have been made. It is a well-known fact that rainfall increases with altitude, a striking example of which is seen in the record for Mt. Washington; and it would be of much assistance in gaining a correct knowledge of the proportional discharge of such a stream as the Connecticut, if accurate information were available concerning the downfall on the more elevated portions of its basin.

Table of temperature and rainfall at points in southern and western New England.

[From Smithsonian records.]

Locality.	Elevation above sea.	TEMPERATURE.						RAINFALL.					
		Years of observation.	Spring.	Summer.	Autumn.	Winter.	Year.	Years of observation.	Spring.	Summer.	Autumn.	Winter.	Year.
	Feet.		°	°	°	°	°		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
New Haven, Connecticut	45	86	46.76	69.63	51.28	28.32	49.00	27	11.24	12.11	11.19	10.90	45.44
Hartford, Connecticut	60	16	47.89	69.75	51.70	29.89	49.81	7	11.08	9.98	11.92	10.81	43.79
Amherst, Massachusetts	267	17	44.17	67.58	47.99	24.15	45.97	39	10.62	12.45	11.16	9.73	43.96
Hanover, New Hampshire	530	20	40.87	65.15	44.76	19.17	42.49	19	9.91	11.09	10.58	9.08	40.66
Stratford, New Hampshire	1,000	13	37.71	62.95	42.68	15.50	39.71	16	9.91	11.18	11.15	8.48	40.72
Randolph, Vermont	700	6	39.60	66.55	45.28	19.02	42.61	8	8.40	10.66	11.29	8.16	38.51
Mount Washington, New Hampshire.	6,293	......	....	....	....	....	....	4	13.96	23.66	19.80	9.70	67.12

NOTE.—In Blodget's *Climatology* it is stated that "the quantity of snow is always large in the New England states, the elevated and northern districts having an average of perhaps 2 feet constantly remaining on the ground in winter". The following are records of snowfall at particular points:

	Inches.
Dover, New Hampshire, average of ten years	68.6
Burlington, Vermont, average of ten years	85.0
Worcester, Massachusetts, average of twelve years	55.0
Amherst, Massachusetts, average of seven years	54.0
Hartford, Connecticut, average of twenty-four years	43.0

According to J. H. Huntington, in an article on "Climatology", in the *Geology of New Hampshire*, observations on snowfall at Lunenburg, Vermont, have shown the average annual amount there to be 83.1 inches, ranging in twenty-five years from 41 to 167.5 inches.

It is hardly necessary to say that the water-power of the section that has been described is of great magnitude and value, but it may be of interest to notice the causes which contribute to those conditions. In the first place, the streams have a rapid fall and large volume. There are very few which can be called sluggish, and even the Connecticut, which approaches most nearly to that character (the Thames is hardly more than an estuary), is interrupted at intervals by heavy rapids and falls. The elevated character of the country is so sustained toward the south that not only are there many minor tributaries there which have large descent, but the main streams, also, have considerable fall within a short distance from tide-water, and at points, therefore, where their accumulated volume is the greatest. Oxoboxo brook, a small stream entering the Thames about midway between Norwich and the mouth, falls not less than 350 feet in 6 miles, and, being supplied by a reservoir, furnishes power to a dozen or more factories in that distance. Within a radius of about 15 miles from Norwich there is a fall of over 140 feet in the Shetucket river, and over 100 feet in the Quinebaug, utilized in part on the former by cotton, woolen, and other factories. On the Housatonic a fall of 22 feet is utilized at Birmingham, at the head of tide-water, and only 11 miles by navigable river from the sound.

The descent of the New England streams is not very uniform. Among the more mountainous sections in the north there are numerous abrupt pitches, and these are also interspersed more or less over nearly all the streams, even to southern Connecticut. But in the more open and moderately hilly districts the drift gravels have to a large extent filled up the beds of the streams, over which the latter run in rapids and rifts, interrupted only now and then by falls over projecting ledges. In northwestern Connecticut the Housatonic falls over 100 feet in probably less than half a mile, and descends more than half this distance in a single plunge; and again, farther south on the same river, at Bull's bridge and New Milford, are other falls of less magnitude. At Norwich, in the southeast, the falls of the Yantic are of great beauty.

The rocks which give rise to the falls are of the harder varieties—granite, gneiss, and mica-schist—and by their unyielding character not only insure the permanency of the falls, but afford secure foundations for dams and other hydraulic works. It is not at all uncommon to meet with dams in this region fifty years old, and I have come across some that have stood securely for certainly a hundred years. This same hardness of the rocks has also prevented the cutting of the deep and inaccessible cañons which distinguish many of the streams in the softer formations of the Rocky mountains.

The volume of the streams is also large in proportion to the extent of country drained. The prevailing steep slopes, the rather shallow soil in many localities, the imperviousness of the underlying rock, and the temperate climate, combine to favor a large proportional discharge. The average annual rainfall for the entire district is probably not far from 45 inches.

As to the uniformity of flow of the streams, some idea may perhaps be gained from what has been said in a previous article on the modes of estimate employed. The term "uniformity" can be used in this connection only in a relative sense, for there is no stream of much size which is strictly uniform in discharge. There are occasional streams so controlled by lakes or reservoirs as to be equally free from considerable freshets and from periods of very low flow, and which have, therefore, an approximation to real uniformity; but most are subject to large fluctuations between high and low water. For practical purposes, however, we may speak of a stream as uniform which is, on the whole, well sustained in the dry season, and which is not visited by very sudden or great changes in volume. The New England rivers have a tolerably good character in these respects. The hard underlying rock, not commonly far below the level of the stream beds, and forming the valley sides, sheds water freely toward them; while the gravels, sands, and clays of the drift favor the reception of rain from the surface and its delivery through springs. The wooded nature of the country also favors the easy percolation of water below the surface of the ground, shades from undue evaporation, and conserves the winter snows; and perhaps above all other causes should be mentioned the numerous lakes and swamps.

Dr. Hitchcock, in his geological report published in 1841, roughly estimated that the state of Massachusetts contained 125 square miles of peat swamps alone; the area of swampy land not containing peat would greatly increase this figure, but I have no data as to its real extent. Percival, in a *Report on the Geology of the State of Connecticut*, made in 1841, mentioned that "swamps abounding more or less in peat are found in every town in the state". The influence both of lakes and of swamps is very marked on streams, and perhaps in favor of the latter of the two. Their great advantage lies in their storing and holding back the rains which would otherwise be too quickly carried off by the water-courses. While lakes accomplish this result in a very important degree, swamps seem even more effective, owing to the obstacles which they oppose to any but a gradual drainage, in their shallow depth and their usual rank growth of grasses and brush.

The benefit accruing to a stream which has these natural regulators is illustrated in the case of the Quaboag river, a tributary of the Chicopee, in Massachusetts. Surrounding its upper course are extensive marshes, which give it a very steady flow, the rise on the West Warren dams not exceeding 18 inches, in an ordinary spring freshet, on an overflow of about 110 feet, and this from a drainage area of 142 square miles.

The value of even the ordinary storage provided along the course of a stream by the mill-dams was well shown in the great flood which swept down the course of the Westfield river, in Massachusetts, December 10, 1878. In a report upon methods for future protection of the town of Westfield, which suffered severely at that time, Mr. Hiram F. Mills, civil engineer, remarked as follows:

> From data supplied by your sub-committee on surveys, I conclude that the greatest quantity of water passing Salmon Falls dam was 53,000 cubic feet per second, from a drainage area of 350 square miles; and at the same time there were entering the area between Salmon Falls and Westfield dam about 1,000 cubic feet per second, from an area of 14 square miles. A part of this 54,000 cubic feet per second was expended in filling the great reservoir, containing probably as much as 100,000,000 cubic feet of water, between these two dams, and a part in flowing over the Westfield dam. Every reservoir that the water fills in its course serves as a regulator, which prolongs the time of flowing past any dam down the stream, but tends to decrease the amount passing at any moment. This is illustrated by the greatest quantity per second which is shown by the data of your survey to have passed the Salmon Falls dam and the Agawam [a] dam; the former quantity being 53,000 cubic feet per second, and the latter, although increased by the drainage from 40 per cent. more area, was but 46,000 cubic feet per second. This decrease in quantity, at the time of highest water, at the lower dam was due to a part of the water from above being used in filling the enormous reservoirs between the two dams, which drained off gradually after the flood had passed the upper dam.

While, as has been said, the effect of lakes and swamps is so helpful in lessening freshets and maintaining a good volume during droughts, their usefulness in these respects is much increased by artificially enlarging their storage and controlling them; in other words, by making true storage reservoirs of them, and instead of permitting their contents to run off at all seasons, as in the natural state, saving them in winter and spring for use during the dry months of summer and autumn. And in this improvement of the New England streams by storage reservoirs seems to me to lie their most noteworthy and interesting feature.

It is very difficult to obtain reliable data as to either the area or cost of these improvements, except in occasional instances. Many of them were undertaken years ago, and neither then nor more recently does much attention seem to have been paid to an accurate record of facts concerning them. It is certainly true, however, that in many cases they have been been built at a merely nominal expense. Natural ponds of several hundred, or even a thousand acres and over, have been raised a number of feet by means of a short and inexpensive embankment, probably not costing more than a few thousand dollars at the most. It is in this manner, by raising the level of some natural pond or lake, that most of the storage reservoirs seem to have been created. They are usually so located among hills that it is possible to raise their surfaces considerably without their flowage spreading out unreasonably far; and these hills often close in at the outlets, so that only a short dam is needed to connect them and control the pond. This sort of topography is, indeed, common through all that portion of New England which I have visited. The courses of the streams are flanked by hills, which successively approach and recede from them, forming what are termed "intervales" of meadow or gently-sloping land.

The class of reservoirs which I have just described is largely of natural formation. A second class is almost entirely artificial, and is formed by throwing an embankment across the course of some small stream in its upper waters, at the foot of an intervale of swampy land. An unusual number of such opportunities have existed and been availed of in eastern Connecticut and the adjoining portion of Rhode Island. Such reservoirs are easily and cheaply constructed, the land for flowage having but little agricultural value, in consequence of

[a] Agawam is about 8 miles by river below Westfield, and the latter 6 to 7 miles below Salmon Falls.

which the land damages are small. It has been stated to me by a manufacturer who had investigated the subject, that on the upper course of the Moosup river, in western Rhode Island, 3,000 acres of reservoir room could be added to the stream by flowing almost worthless swamp land, at an expense of only $4,000 total for flowage and improvements, and others agree that the opportunities there for large storage are very favorable. The reservoirs of this class have the advantage over those first mentioned, that in proportion to their cubic contents their storage is generally more accessible, because of their being comparatively shallow; though it is true, on the other hand, that they suffer greater loss by evaporation, and receive less water from deep-seated springs. Many of the natural ponds are so deep that a large share of the water they contain cannot be drawn out at all. This makes no difference, to be sure, in the available amount of water for power, provided the topography is such that the proportion of annual rainfall received can be stored above the level which is accessible, but that cannot always be done.

A third class of reservoirs, and the least numerous of all, is constructed by building a high embankment or dam across a narrow gorge. The area available for flowage in this case being small, an adequate storage has to be provided for by increase of depth, and hence by high dams. The reservoirs thus built are probably the most expensive in construction, and certainly the most dangerous to maintain, of any that have been described. There should be little difficulty in properly building and maintaining an embankment 5 or 10 feet high, but it is quite another thing to obtain equal security with an embankment 30 or 40 feet high.

The construction and maintenance of storage reservoirs are often carried out by individual mill-owners on a stream, but perhaps as commonly by associations of the various parties to be benefited. The expenses of construction and repairs are assessed upon the members, either in proportion to the fall owned, or upon some other basis. The system seems generally to work well, but cases are not uncommon in which members in some manner evade their assessments, or in which parties refuse to contribute at all, and so enjoy the benefits of the improvements but escape the burdens.

The change which may be brought about in the flow of a stream by properly developing the storage capacity of its basin is strikingly seen in the instance of the Pachaug river, a tributary of the Quinebaug, in southeastern Connecticut, draining about 60 square miles. Twenty years ago the Ashland cotton-mill, located near the mouth, contained seventy looms, but could only run a portion of the year, and had much trouble from lack of water. The stream was afterward finely reservoired, however, and now the Ashland mill carries five hundred looms, and has not been stopped more than a day and a half by low water since 1865.

Notwithstanding that the New England streams are fairly well sustained in the dry season, there are certain conditions which act unfavorably upon them. The rainfall in summer is perhaps slightly greater than during the other seasons, yet it is not sufficiently so to counteract the heavy evaporation of that period, and so, for the machinery employed, there is generally a deficiency of water in the streams for two or three months in the year, and an excess for eight or nine months. The draining of swamps and the cutting of timber also act to materially injure the uniformity of flow. As was remarked to me by a Massachusetts mill-owner, the farmers and manufacturers are directly opposed as regards the draining of swamp-land. The former wish to reclaim as much surface as possible for cultivation, and it is said that a Massachusetts agricultural society encourages such improvements by premiums. On the other hand, manufacturers appreciate the value of swamps in maintaining the low-water flow of their mill-streams, and desire them to remain.

Some of the effects on the streams of the wholesale destruction of timber are perfectly well known. It is certain enough that they are subject to more sudden fluctuations and are less sustained in droughts than before the country was cleared. These results are matters of common observation among men whose memories reach back over fifty, forty, or even twenty years; it is a universal complaint in New England that the mill-streams are less reliable, excepting, of course, where artificially reservoired, than they were that length of time ago, and this is due both to the clearing of land and to the drainage of swamps. The principal freshets in the region under discussion are caused by the melting of snow in the spring, and while the effect of forests is, by shading the ground, to prevent this going on too rapidly, so, on the other hand, their destruction lays the surface open to the direct action of the sun, and gives good opportunity for a quick wasting away of the snow. The record of the heights of freshets in the Connecticut river for thirty-five years back shows that in this stream, whether we have regard to the highest freshets of the year or to the highest occurring during the first five months, which latter may be supposed to have a connection with the melting of snow, there has been a considerable increase in the average heights reached.

Table showing average heights of freshets in the Connecticut river. (a)

HIGHEST OF THE YEAR.		HIGHEST OF FIRST FIVE MONTHS.	
Period.	Average height.	Period.	Average height.
	Feet.		*Feet.*
1844 to 1849	18.54	1845 to 1848	18.56
1850 to 1859	20.52	1850 to 1859	19.86
1860 to 1869	21.18	1860 to 1869	21.18
1870 to 1879	21.71	1870 to 1879	21.06

a Compiled from record given in report on survey of the river below Hartford; see *Report Chief of Engineers*, 1880.

While it seems evident that from some cause, which may reasonably be assumed to be the clearing up of the country, the tendency is to a gradual increase in the average height of freshets, it is not so certain that the *extremes* of fluctuation are any greater now, as maintained by some, than formerly; indeed, concerning the Connecticut, the reverse appears true. General Theodore G. Ellis, in an elaborate report upon this river, (*a*) speaks thus of its freshets:

The Connecticut river is subject to freshets of considerable height, which occur principally in the spring, when the volume is swollen by the melting snow, although occasional floods have occurred in every month of the year except July and September. The highest freshets generally take place in the spring. There was one remarkable exception, however, in August, 1856, when the water at Hartford rose to a height of 23 feet 4 inches above low-water mark. This was caused by unusually heavy rains which occurred at that time. The freshet of May, 1854, is the highest known below Holyoke. This was 29 feet and 10 inches above the low-water mark of the Hartford gauge. The freshet of April, 1862, was the highest known on Holyoke dam, and was probably the highest in the river above that point. Previous to these two freshets the flood of 1801 was the highest on record, and formed the basis of most of the points of reference along the river previous to 1854.

The lowest water known was that of August, 1858.

The fact is, I think, that remarkable freshets, as well as periods of extremely low water, are to such an extent the result of accidental combinations of favoring conditions—such as sudden rains upon a frozen surface, rapid thawing of a heavy body of snow; or, on the other hand, an uncommonly prolonged drought, or a drought following a season of small rainfall—that it is not fair to assume them as necessarily caused by the clearing away of the forests.

In speaking of the effect of melting snow upon such a stream as the Connecticut, for instance, an important circumstance to be noted is its position in a north-and-south line. In this direction it extends some 275 miles, covering quite a range of climate. The average temperature of March at Hartford is not gained at Stratford, New Hampshire, till April, nor that of April at Hartford till May in Stratford. The chances are, therefore, that the melting of snow will extend rather gradually up the valley and its effect upon the stream be prolonged, whereas if the river lay in an east-and-west direction, having but little range in climate, a much more sudden and perhaps disastrous freshet rise might be anticipated.

Low water is the principal disadvantage encountered in this section in the use of water-power. Freshets do not often endanger properly-constructed works, and the rapid slopes of the streams carry off the floods so quickly that an absolute stoppage of operations is seldom necessary, and serious trouble from backwater lasts but a few days at the most. Quite thick ice forms in the winter-time on the rivers, and during the spring break-up gorges occur at some points, but, in general, the action of floating ice is not destructive, and largely because of the extensive improvements in the way of dams and reservoirs, which always ameliorate the natural condition of a stream. In the ponds formed by the dams the ice is usually held back until so rotten that when broken it can do little harm, and in going over successive dams it is soon shattered into fine fragments.

A somewhat troublesome feature during the winter season is the presence in the streams of what is called in New England "anchor-ice"; farther west, "slush-ice", and which abroad is variously known as "ground-ice", "bottom-ice", and "loppered-ice". We are most familiar with ice as formed upon the surface of water, but anchor-ice collects on the beds of streams, from which, in rising, it often tears up small stones or masses of gravel. It is crystalline in structure, and in the water resembles a kind of fungus or vegetable growth; at times a stream will be seen full of little masses of anchor-ice floating along near or at the surface. Its consistency is often very slight, so that if an attempt is made to grasp it in the hand it readily melts and disappears. It forms on the head-gates of canals, on the racks at the entrances to flumes, and if allowed to pass into a wheel-pit is liable to stop the wheel. Although the latter experience is an extreme one and not commonly met, a large amount of labor in the aggregate has to be performed on the streams in the northern part of the United States in keeping clear the racks and head-gates.

Anchor-ice is confined mainly to swift-running streams having gravelly or stony beds, and all mill-owners agree that it ceases to hinder them as soon as the rivers become frozen over on the surface. Streams fed largely from ponds and lakes near at hand, the waters of which are warmer than those running in the usual channels, are free from this form of ice. In my visits to the various streams I made many inquiries of manufacturers concerning anchor ice, but though all were familiar with its occurrence, few had observed with much closeness the circumstances attending its formation. At Windsor Locks, on the Connecticut river, much trouble is encountered from anchor-ice, owing to its collecting upon the head-gates of the canal, and the consequent clogging, but it is said to be noticed only when there is a very cold wind blowing. For 18 miles above the dam the river is sluggish and free from rapids, but is then interrupted by the heavy falls at Holyoke. Near Olean, New York, on the Allegheny river, a prominent mill-owner, long familiar with the stream, stated to me that anchor-ice, or, as he called it, "slush-ice", was of common occurrence there; that when previously running upon the surface of the river, the coming up of a south wind would cause it to settle and to begin clogging the water-wheels, and that it was generally considered on that part of the river that the settling of the ice betokened a coming thaw.

a Appendix B 14, *Report Chief of Engineers for* 1878.

In an article by Colonel Jackson, on the "Congelation of the Neva at St. Petersburg", (a) he states having observed ground-ice in that river where the latter had a depth of 35 feet and was covered with a coating of surface-ice 3 feet thick, the ground-ice appeared not only upon the bottom of the river, but also beneath the surface coating, and was made up of little flakes or scales.

Various hypotheses have been advanced to account for the formation of anchor-ice. Dr. Farquharson claimed it to be the result of radiation of heat from the river bed, and to be formed on the same principle as dew. The Rev. Mr. Eisdale, of England, stoutly maintained that it was produced by little spiculæ of hoar-frost falling from the atmosphere into the water. But the principles which seem to me to best explain the phenomena of anchor-ice are those advanced by M. Arago, and thus briefly given in the English Cyclopædia:

1. The reversion, by the motion of the current, of the hydrostatic order, by which the water at the surface cooled by the colder air, and which at all points of the temperature of water under 39° F. would, in still water, continue to float on the surface, is mixed with the warmer water below; and thus the whole body of water to the bottom is cooled alike by a mechanical action of the stream.

2. The aptitude to the formation of crystals of ice on the stones and asperities of the bottom in the water wholly cooled to 32°, similar to the readiness with which crystals form on pointed and rough bodies in a saturated saline solution.

3. The existence of a less impediment to the formation of crystals in the slower motion of the water at the bottom than in the more rapid one near or at the surface.

That the whole body of water is thoroughly chilled, and in a condition to crystallize readily upon any hard nucleus, may be shown, I am told, by lowering a pole into the stream, when it will speedily become coated with the anchor-ice. The masses of ice which cling by adhesion to the stones on the river bed grow in size, and at length attain sufficient buoyancy to loosen their fastenings and rise to the surface. It is often said by observers that this action is most marked soon after sunrise.

Less difficulty seems to be experienced from the source mentioned where the mill-ponds are large and deep, and water is brought directly from them to the wheels, or, at least, is passed through canals of good depth, than where the ponds are small and shallow, and water is carried a considerable distance in canals of slight depth, especially if their bottoms are stony. The most common mode of dealing with anchor-ice is to rake it away by hand from the racks, although occasionally the plan is tried of introducing a jet of steam into the flume to disperse it.

In connection with the streams it is interesting to notice the special kinds of manufacturing which have come to distinguish certain of them. Thus, on the tributaries of the Thames we find cotton- and woolen-mills; on the Connecticut and upper Housatonic, paper-mills; on Miller's river, various manufactures in wood; on the Naugatuck and at Birmingham, Connecticut, metal-working establishments; at the outlet of Pocatopaug lake, Connecticut, bell manufactories, and so on.

Great as has already become the use of water-power in the section draining toward Long Island sound, the opportunities for further development are still ample, and are being frequently availed of. In my own observation, the improvement of new privileges and the more extended use of old ones have gone on quite largely in the past two years (1880–'82), and these improvements have generally been of important powers, and are characterized by their substantial and expensive nature. New England certainly possesses some very valuable advantages for manufacturing in the abundance and desirable qualities of her water-power, in her nearness to tide-water, her established and well-equipped lines of communication with the coal districts and great centers of trade, such as New York and Boston, in her compact and numerous population, in her possession of a large and prosperous class of skilled laborers, in the bias and inclination which her people have acquired for manufacturing pursuits, and in the extent of her available capital. The last item must not be underrated. Very many of the manufacturing companies have a capital ranging from $1,000,000 upward. Some of the largest cotton-mills, when stocked with their elegant machinery, are said to have cost $1,000,000 or $2,000,000 each, and a large additional capital is evidently required for carrying on business of such magnitude. For cotton manufacturing, the location as regards obtaining raw material is less favorable than in the South: for the manufacture of paper, which has assumed great prominence rags and wood-pulp are easily obtained, and the abundance of pure water is an essential advantage.

One great obstacle to the improvement of many water-powers is the rather grasping and short-sighted policy pursued by adjoining land-owners or by the owners of the privileges themselves. These are often held for speculation at unreasonable prices. If the development of a water-privilege is considered by a company of capitalists, meadow-land, which must be bought for flowage, and which has, perhaps, produced a moderate crop of coarse grass, at once assumes a wonderful value in the eyes of its proprietors, and is sometimes hardly to be purchased at any price. Although this experience is probably exceptional, it has certainly prevented, in some instances, the establishment of important enterprises. It would seem to be much the better plan for the farmers to encourage, by all reasonable means, the introduction of manufactures. Farming is not regarded as a very profitable industry in New England, but its gains ought surely to be increased by the founding of villages which must be supplied with farm products. Not only this, but the development of manufacturing points tends to a substantial increase in the value of real estate, and for the sake of that advantage it is sometimes thought good policy to give away water-rights to desirable companies without charge.

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a *Journal of the Royal Geographical Society*, Vol. V.

I.—THE THAMES RIVER AND TRIBUTARIES.

THE THAMES RIVER.

This stream drains the eastern part of Connecticut and small portions of Rhode Island and Massachusetts, the area of its basin being 1,450 square miles. The country thus included is almost everywhere hilly, is tolerably well wooded, though with a young growth, and contains many natural lakes and ponds which have been improved for reservoirs. Much of the land on the hills is stony and poor, with little value for anything but pasturage. The principal industry of this section is its manufacturing, which has assumed great importance, especially in the matter of cotton and woolen goods. The first successful water-mill for the manufacture of cotton goods in the United States was completed and put in operation by Messrs. Almy, Brown, and Samuel Slater, early in 1793, at Pawtucket, Rhode Island,(a) and the period which has since elapsed has witnessed a wonderful growth in this branch of enterprise, both in Rhode Island and in the adjoining portion of Connecticut, as well as in other parts of the eastern states.

The Thames river is formed at Norwich, New London county, Connecticut, by the union of the Shetucket and Yantic. It runs southerly and empties at New London, at the eastern extremity of Long Island sound. Its width generally ranges from a quarter to a half mile, except near the mouth, where it widens to a full mile and forms the magnificent harbor of New London. It is a tidal stream, the mean rise and fall of tide at New London being 2.5 feet, and at Norwich 3.1 feet.(b) The distance from the latter point to the mouth is about 15 miles, which is navigable for vessels of 12 feet draught; in 1880 the shallowest part of the channel had a depth of at least 10 feet at mean low water, and operations have since been carried on by the national government with the view of obtaining a depth of 14 feet at that stage.

The river is bordered on either side by high hills, and is a most beautiful stream. Below Norwich no tributaries are received except a few small streams; one of these, however, Oxoboxo brook, which is fed by a large reservoir, supplies power to a number of factories.

TRIBUTARIES OF THE THAMES BELOW THE JUNCTION OF THE SHETUCKET AND YANTIC RIVERS.

I shall speak only of those tributaries coming in from the west, small, as already stated, and including Alewife, Oxoboxo, Stony, and Trading Cove brooks.

The high hills which border the Thames are here thickly wooded, except toward the lower ground, with chestnut and oak. The surface is very rocky, displaying many granite and gneiss bowlders and outcropping ledges. The mills and dams on the Oxoboxo are in numerous instances built of those varieties of rock, quarried in the valley. The surrounding country has small agricultural value, and is but little cultivated; corn, potatoes, and grass are the principal productions.

Alewife brook is a little stream, half a dozen miles long, and draining about 10 square miles lying in the towns of Montville and Waterford. At the head is an artificial reservoir 1 mile long and reaching half the width, with a dam 20 feet high at the outlet; it can be pretty thoroughly drawn out, but does not appear to be so well sustained by springs as Oxoboxo reservoir to the northward. It is said that by means of a dam 40 feet high a reservoir can be constructed between the two Robertson privileges, 2 miles long and three-quarters of a mile wide. The site is favorable for a dam, and the entire expense for flowage and construction is estimated not to exceed $6,000. It is claimed that with this reservoir built the mills could run at full capacity throughout the year; as it is, the supply of water is sufficient only about six months in the year, say from January to July, after which the mills shut down. There are four privileges in use on the stream, covering a total of about 76 feet fall, and all utilized by paper-mills. The lowest and uppermost mills are owned by O. Woodruff, and the two intervening by J. Robertson's Sons. At the Robertson mills an aggregate of about 90 horse-power is in use.

Oxoboxo brook heads in a reservoir of the same name, whence it flows southeasterly across the town of Montville, draining 13 square miles. The reservoir contains about 160 acres, and is a natural lake raised, and having its flowage increased, by a granite dam at the outlet; it is quite deep, and a considerable portion of its contents can not be drawn out on that account. The Uncasville Manufacturing Company owns the reservoir, but so regulates the supply from it as to accommodate the other manufacturers.

The valley of the stream is narrow and hemmed in by steep slopes, thickly wooded on their upper portions, but having a thin covering of soil and rapidly shedding rainfall. This valley derives its importance solely from manufacturing, and has scarcely any population aside from that connected with the mills. The New London

a Bishop's *History of American Manufacturing*.

b As stated by Major J. W. Barlow, corps of engineers, U. S. Army.

Northern railroad crosses at the mouth, and Montville station, which is located there, is stated to rank third among the stations on this line as regards the amount of freighting. Goods were formerly shipped by water from the mouth of the stream, but that practice has been given up. All transportation from the mills to Montville station is by team, though it is practicable to construct a railroad up the valley, and the subject has been somewhat considered.

The brook runs over a gravelly bed, underlaid by rock, which frequently crops out. Its fall is rapid, amounting to over 350 feet in the 6 miles from the reservoir to the mouth. The mills succeed one another closely, each dam setting back the stream nearly or quite to the next one above. The ponds are, as a rule, small and of little account; the pond at the Uncasville mill is larger than the rest, however, and would of itself probably supply the mill for a day or two. The dams are short, and usually consist of an embankment on one or both sides of the stream, with a roll-way (*a*) of granite or wood; they appear to be tight, and two or three are very solidly constructed. Water is conveyed to the wheels variously by wooden flumes, iron tubes, and canals carried along the side hills; the canals are short, seldom exceeding a few hundred feet in length. The mills are of fair size and well built, frequently of stone. They have generally increased their capacity in recent years, and, in consequence, have been obliged to introduce steam for auxiliary power, relying more or less upon that for three months in the year.

The flow of the stream, of course, depends upon the manner in which it is regulated at the reservoir, but it was represented to me to be ordinarily about 30 cubic feet per second. It is said that the dry-season flow could be considerably increased by a reservoir which might be built, at reasonable expense, on Fox brook, which joins the Oxoboxo at Oakdale. The annual rainfall in this section is about 50 inches, and unless the area drained is larger than appears on the map which I have used, a greater average flow for the year than 20 to 25 cubic feet per second, continuous through 24 hours of the day, cannot be expected.

August 25, 1877, after a very heavy rain, of the nature of a "cloud-burst", during which 8.5 inches of rain were reported to have fallen in three hours, the upper mill-dam, below the reservoir, gave way, and carried out, in succession, nearly all the dams below, causing a damage estimated at $40,000.

The manufacturing on this stream is mainly of cotton and woolen goods and paper. Some details concerning the privileges are given below:

Water-privileges on Oxoboxo brook (in order from the mouth).

Firm.	Manufacture.	Fall.	Horse-power utilized.	Remarks.
		Feet.		
Johnson & Co.	Dye-woods and extracts	14		Privilege is nominally rated at 50 effective horse-power, which can be realized nine months in the year.
Uncasville Manufacturing Company.	Cotton goods	40	167	Dam has 60 feet of roll-way of solid granite masonry; remainder is granite facing filled in with gravel. Can realize about two-thirds capacity of wheels in dry times.
Pequot Mills	Cotton goods	16 36	42 136	Granite dam, 30 feet high. Privilege is in two successive falls; an iron penstock carries water to the upper mill, and a race thence to the lower mill.
R. G. Hooper & Co.	Unoccupied	12-16		
Do	Cloakings	25-26	55	
Palmer Brothers	Bed comfortables and cotton rope	13	25	
A. Hurlbut	Twine and cotton cordage	8	20	
C. M. Robertson	Paper	22	40	
Do	do	40	60-65	
Do	Small grist-mill and shoddy-mill.	20	25-30	Privilege owned by C. M. Robertson.
Do	Unimproved	8-10		
Palmer Brothers	Bed comfortables	26	90	Masonry dam with gravel embankment. Race and flume 500-600 feet long. Can run full capacity nine months in the year, and 60 horse-power the remainder.
C. F. Schofield	Woolen goods	12	24	1-set mill.
B. F. Schofield	do	11	20	1-set mill.
Do	Unimproved	20		
Do	Saw-mill	19	20	
Do	Unimproved	15-20		Between saw-mill and reservoir.

Stony and *Trading Cove brooks* are little streams lying to the north of Oxoboxo brook, and draining 8 and 12 square miles, respectively. The first has a grist- and saw-mill near the mouth, and a shingle- and grist-mill some distance above. The fall is rapid, and there are reported good opportunities for reservoirs, but there is now very little water running in the dry season.

Trading Cove brook has a small woolen-mill at the mouth, and one or two powers in use farther up. It is not thought to be as good a stream as Stony brook; its fall is slight, and in the summer of 1882 it ran nearly or quite dry.

a In New England the term "roll-way" is applied to that portion of the dam between the abutments, and over which the stream flows.

THE SHETUCKET RIVER.

The Willimantic and Natchaug rivers unite, immediately below Willimantic borough, to form the Shetucket, which then runs to the southeast and joins the Yantic at Norwich. It is 18¾ miles long, and lies mainly in the towns of Windham and Sprague and between those of Norwich and Lisbon. Norwich, at the mouth, is a wealthy and beautiful city, containing a population of 15,000, and is the center of important manufacturing interests. Three miles above the city the Quinebaug enters the main river from the east, and is, in fact, of more consequence than the Shetucket above their junction, containing a larger area in its basin, and being better supplied with reservoirs. Between this point and Willimantic, Little river and Merrick's brook are received from the east, and Beaver brook from the west, but they are all small streams.

The only elevations which I have been able to obtain for the Shetucket and its tributaries are those furnished by an old survey, instituted by citizens of Norwich in 1825, the record of which was kindly loaned me by Moses Pierce, esq., of that city. In view of the large developments of water-power which have since been made on those streams, and some of which, I am informed, have been based directly upon the data supplied by the survey, it is interesting to recall the words of its originators: "We, the subscribers, believing that the improvement of the unoccupied water-privileges on the Quinebaug and Shetucket rivers would be a great public benefit, and for the purpose of ascertaining the number, magnitude, location, and value of the privileges on said rivers, hereby agree to pay the sums affixed, etc. * * * Norwich, January 24th, 1825".

Mr. Pierce states that the survey has been found correct whenever there has been occasion to verify any portion, and it is fair to assume that the rest is equally reliable. It extended from tide-water up the Quinebaug river to Danielsonville, the entire length of the Shetucket, and about 3 miles above its head on the Willimantic and Natchaug. The total fall in the Shetucket river was found to be 144.25 feet, equivalent to an average of about 7.7 feet per mile, distributed as below:

Table showing fall in the Shetucket river.

[From survey of 1825.]

Section of river.	Distance.	Fall.	
	Rods.	*Ft.*	*in.*
Junction Willimantic and Natchaug to Bingham's bridge	452	12	8
Thence to Island bridge	560	7	10
Thence to lower end of Dyer's ditch	302	7	8
Thence to foot of falls, below Manning's bridge	364	8	3
From foot of falls (290 rods below Manning's bridge) to mouth of Waldo's brook at Wood's bridge	574	11	4
Thence to tide-water	3,748	96	6
Total from junction of Willimantic and Natchaug to tide-water	6,000	144	3

NOTE.—From the junction of the Willimantic and Natchaug nearly half-way to Norwich, or to Baltic slackwater, the fall, amounting to about 54 feet, is unimproved. For the remainder of the distance it is practically all developed.

The points on this river at which it is used for power are, in order from the mouth, Norwich, or perhaps more properly Greeneville, a suburb of the city, Taftville, Occum, and Baltic; between Baltic and Willimantic there are two unimproved privileges, which will be described later.

The drainage area of the Shetucket is 1,245 square miles, of which 512 are above its junction with the Quinebaug, while 725 belong to the latter stream. Excepting those of the Quinebaug basin, the principal lakes and storage reservoirs of the Shetucket drain into it through the Willimantic and Natchaug rivers, and hence benefit the whole length of the river below. Their location and approximate areas are as follows:

Lakes and reservoirs in the Willimantic and Natchaug basins.

Name.	Location.	Approximate area. (*a*)	Outlet.
		Acres.	
Staffordville reservoir	Northeast part of town of Stafford	200	Furnace brook.
Square pond (reservoir)	Ellington and Stafford	*175	Reaches West branch of Willimantic river.
Orcuttville reservoir	Town of Stafford		Middle river.
Wangumbaug lake (reservoir)	Town of Coventry	*450	Outlet runs to Willimantic river.
Bolton reservoir	Northern part of town of Bolton	500	Hop river.
Columbia reservoir	Town of Columbia	282	Drains to Hop river.
Black lake	Western part of town of Woodstock	*80	Drains to Natchaug river.
Crystal lake (reservoir)	Eastford and Woodstock	200	Still river to Natchaug.
Eastford reservoir	Town of Eastford	200	Drains to Natchaug river.

a Not very accurate probably, but the best estimates I could obtain; where marked by a star (*) areas were measured on map of state of Connecticut.

The Shetucket river rises rapidly after rains, usually coming up for about twelve hours after a storm has ceased, and then gradually falls away; even an ordinary rain has an important effect upon its volume, and when the supply is low will sometimes give the mills plenty of water for several weeks. There is very little low ground along the stream, and the banks are not overflowed. Backwater causes but little hindrance and never any stoppage to the mills. At Baltic the working head is sometimes reduced 3 or 4 feet, but the trouble is only experienced during a very few days in the year. A depth of 4 feet of water flowing over the dam (roll-way 515 feet long) is considered quite a large freshet rise. At Taftville the ordinary spring-freshet rise below the dam is 5 or 6 feet, and the hinderance from backwater is stated as even less than at Baltic, amounting to only a foot or two net reduction of head, and that for but one or two days.

Neither is there any trouble worth mentioning from ice. Whatever floating ice comes down from the upper river runs out on to extensive flats near Scotland station and melts there; little ice, therefore, except that formed below Scotland, goes over the Baltic dam, and at Taftville the depth of water running over the crest of the dam is so small, not amounting to more than 3 or 4 feet in common freshets, that the ice does not escape from the pond until so thoroughly rotted as to be harmless.

Although, as I have stated, the ordinary freshets in the Shetucket are not serious, yet, in at least two instances, it has been visited by destructive floods. March 26, 1876, the river rose to such a height as to run 10 feet deep over the Taftville dam, and 12 or 14 feet deep over that at Greeneville. This was on Sunday. Through the preceding week heavy rains had filled all the reservoirs, and during Saturday night drenching showers carried the streams out of their beds. The storm was general and disastrous in Connecticut, Rhode Island, and Massachusetts; it was stated that in the vicinity of Providence 4.06 inches of rain fell during Saturday and Saturday night, making 7.66 inches in six days. The losses by this freshet were great throughout the section in which it occurred, and were estimated to amount to several hundred thousand dollars in eastern Connecticut. Dams were carried away, mills were injured, warehouses submerged, and railroad embankments washed out. The larger part of the damage was along the course of the Shetucket river. At Baltic a portion of the dam and part of the mill were carried away; the bulkhead of the Occum dam was washed out, and the mill suffered injury; and at Taftville the embankment forming a part of the dam would probably have been overcome, and the splendid mill destroyed, had not the former been protected by a hastily-built breastwork of rock and bales of cotton-waste.

Again, almost exactly a year later, on the morning of March 27, 1877, the storage reservoir at Staffordville gave way, and caused heavy losses in the town of Stafford, and especially at Stafford Springs.

Improved privileges.—Ascending the river, the first power is that at Greeneville, immediately above Norwich. The river in this vicinity is skirted by high hills, rising steadily from the water, and but slightly timbered; it is about 300 feet wide between banks, with a bed composed of gravel and small bowlders.

The old Greeneville dam is about a mile and a half from the Thames. It was built in 1829, but has since been raised; it is a timber and stone structure, with stone abutments, and cost, say $50,000; the roll-way is 326 feet long and 14 feet high. Above is a pondage of perhaps 125 acres. The canal follows down the west bank, and is seven-eighths of a mile long, from 30 to 50 feet wide, and 10 feet deep.

The mills supplied with water are, in order, F. B. Durfee's grist-mill, the Hubbard paper-mill, and the mills of the Norwich Bleaching and Calendering Company, the Chelsea Paper Company, and the Shetucket Manufacturing Company (cotton goods). The total rated power of wheels in use is stated at 1,600 or 1,700 horse-power.

The privilege is operated by the Norwich Water-Power Company, which has sold absolutely to the various mills their rights to water, reserving a certain annual rental amounting to about $130 per 1,000-spindle power. Such measurements of water as are carried on are made at the gates opening from the canal. These gates are usually three in number at each flume, each gate-opening being 4 feet wide. In measuring, the gate is raised to a point leaving a small head between canal and flume; this head is measured, and the flow determined by formula. It is designed to introduce flume-measurements in time.

The privilege owned by the water-power company covers certainly 19 feet and 5 inches, extending from tide-water to the foot of what are known as the "Quinebaug falls", and an additional foot of fall is also claimed. The heads actually obtained at the mills range from 14½ to 17 feet, according to their position along the canal. So far as regards a thorough utilization of the power of the river, the plan of development adopted here is not the most desirable. If the dam could have been located considerably farther down-stream, and water carried to mills at tide-water, the entire benefit of the fall might have been received and the pondage substantially increased. The cost of the dam would have been greater, on account of its additional height; but, on the other hand, there would have been no necessity for building up a village separate from the city, as has been done at Greeneville.

At this point the Shetucket includes in its volume the water discharged by the Quinebaug. During high water the effective head at the mills is, of course, somewhat diminished by backwater, but not for more than one or two days in the year is the hindrance so great that they have to shut down. The common freshet depth on the dam does not exceed 6 or 7 feet. In the river below, the water sometimes rises nearly to the top of the canal bank, and has even been known to cover it from sight. The chief trouble is experienced from low water, and some of the mills use steam as auxiliary power. The supply of water is sufficient to run them all at full capacity six to seven months in ordinary years, and perhaps three-quarters capacity the remaining months. The pond is sometimes drawn

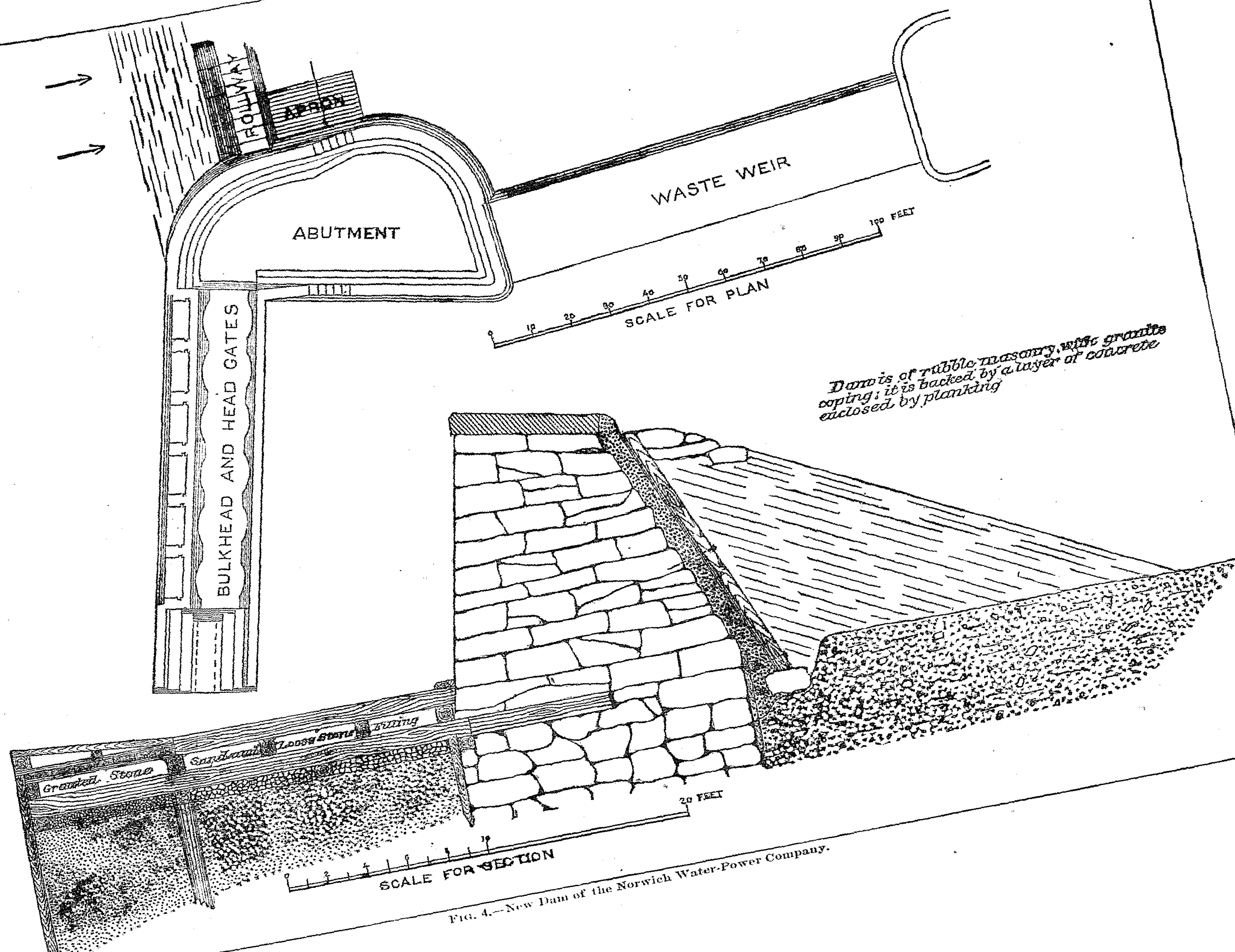

FIG. 4.—New Dam of the Norwich Water-Power Company.

down 18 inches, and there is seldom in summer any water running over the dam, even at night. During low stages a certain priority in rights to water exists; the Shetucket Company stands first, and must be supplied in preference to any of the other mills. The manufacturing concerns on this privilege are all of large size; they are conveniently located between the canal and the river, with the Norwich and Worcester railroad on the opposite side of the canal.

In September, 1881, work was begun upon a new dam at Greeneville, about 1,200 feet below the old one. The roll-way of this dam is to be 400 feet long; the masonry work is 15 feet high and is set slightly into the river-bed, its crest being on the same level with that of the old dam. The bed of the river is here composed of gravel containing cobble-stones or small bowlders, and retains that character to a considerable depth, probably 30 feet at least. The dam is 15 feet wide at the base and 7½ feet wide at the top; the face batters 2 inches, and the back 5 inches, to the foot. The work is in rubble masonry with cut-granite coping; the rubble is composed of a quartzose rock of varying composition. The back slope is to be faced with concrete to a thickness of 1 foot, secured in place by planking.

An apron of timber projects 22 feet below the dam. It has an upward slope at the down-stream end, attained by a "pitch-plank", designed to throw the water out and permit it to fall in such manner as not to produce scour in the river-bed at the end of the apron. The apron is of two thicknesses of timber, the intervening space filled in with sand and stone, except under the incline, where it is to be grouted stone. At the edge of the apron sheet-piling is driven 11 to 11½ feet into the river-bed; another row is driven 5 feet deep at the foot of the back slope of the dam. This precaution is to prevent leakage and scour under the structure. The material of the apron is hemlock at the bottom and yellow pine and oak at the top. The abutments are curving in plan, and built of rubble. The bulkhead is on the west side; it is of rock-faced masonry, and will contain six gate-openings, each 10 feet square.

Work on this dam was begun in September, 1881, as has been stated, but discontinued during the winter. The completed work was diked in, and no trouble experienced from high water. Upon the return of favorable weather work was resumed, and in August, 1882, was well advanced. At that time the upper dam diverted nearly all the flow of the river into the canal, and very little reached the work. The new structure was being built out simultaneously from both shores; it was expected to be completed during the fall, at an estimated total cost of about $60,000.

The next privilege is occupied by the Ponemah mill, at Taftville. This power is a short distance above the confluence of the Quinebaug and the Shetucket, and about 4 miles from Norwich. A spur from the Norwich and Worcester railroad, a mile and a quarter long, runs to the mill.

The river bed and banks are at Taftville composed mainly of gravel, and at a slight depth a sort of hard-pan is met, which affords the finest of foundations. One end of the mill rests upon rock, a kind of granite, which was quarried and worked into the foundations; a pocket of sand, which was used in making mortar, was also found on the site of the mill. There is no good brick clay in this section, however, and the bricks of which the mill is constructed were brought from Dayville, about 25 miles north on the Norwich and Worcester railroad.

The structure is indeed a splendid one. The main mill is 750 feet long by 74 feet wide, and 5 stories high, with an L 228 by 61 feet, and 4 and 6 stories high. It contains 108,000 spindles and has a capacity for about 2,500 looms. Another large building, to be used exclusively for weaving, was being constructed in 1882.

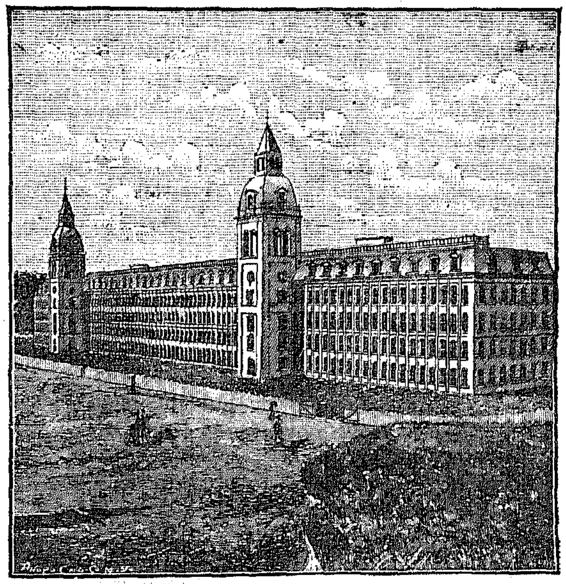

FIG. 5.—Ponemah mill at Taftville.

Some 1,200 hands are employed, and with the completion of the new works the number will be increased to at least 1,500. The manufacture comprises more than 200 styles of lawns, cambrics, and fancy goods. Very fine numbers of thread are used, and it is said that no mill in the United States makes finer goods than the Ponemah; and still higher numbers of thread are before long to be employed. The enterprise of manufacturing was begun at Taftville more than ten years ago, but became embarrassed financially and the property was sold. The present company purchased while the mill was only partially complete, finished its construction, and stocked it with the very best machinery.

The dam has a novel shape, which has not been observed elsewhere on a scale of any importance. It consists of four elliptical sections, separated by piers. It is thought that in time the village in which the operatives live will have to be extended to the opposite side of the river, and the dam has been built in the manner described in order that the piers may serve to bear the superstructure of a bridge. The piers are 8 feet wide at the base and 6 feet at the top; the elliptical segments are each 100 feet in span, so that the entire length of dam between abutments is 418 feet, measured in a straight line; if we take into account the supplementary embankments and the bulkhead, (a) this length should be increased to about 800 feet. The dam is of rubble masonry, 16 feet wide at the base and 8 feet at the top, the coping-stones being a little shorter, however, or 6 feet; the height of the structure is 24 feet,

a The term "bulkhead" is used to indicate the masonry or timber work in connection with the head-gates at the entrance to a canal.

and the face has something of a batter. The apron is a heavy crib-work, 4 feet deep, and projecting 24 feet from the foot of the dam; the last few feet have an upward slope in the same manner as already explained in connection with the Greeneville dam. The west bank at Taftville is rock, while the river bed and east bank are gravel. In building the dam the river bed was excavated till a firm material was reached. The trench was then filled with sifted puddle, inclosing a line of sheet-piling which projects 4 feet below the bottom course of stone and is built into the masonry; there is also a line of priming at the end of the apron.

The abutments are very heavily built, of masonry, are curved in plan, and rise 13 feet above the crest of the dam. An embankment connects the west abutment with the bulkhead. The latter is constructed of granite masonry, has five 8-foot arched openings, and two parapets, it being used as a bridge. The hoisting-gear for the gates is operated by hand-wheels, which turn a horizontal shaft acting upon the different racks. The Taftville dam was built from 1867 to 1870, and its cost complete is roughly stated at about $100,000.

The canal is 50 feet wide at the bottom, 60 feet at the top, and inclosed by masonry walls. It has a total depth of 20 feet, 10 feet above and 10 feet below the crest of the dam, the additional depth being designed to carry freshet water and so prevent, as far as possible, loss of head from backwater. It runs from the bulkhead a short distance to the mill, passing under one end and continuing to the center, opposite which are located the wheels. The tail-water passes through arched ways under the head-race, and soon escapes into the river at the rear of the mill. The canal or head-race is 400 feet long from the head-gates to the center of the mill; the tail-race is 228 feet long and 60 feet wide. The short races employed here are to be noticed. The dam is located well down-stream on the privilege, giving a large pondage above; the water is promptly delivered to the wheels through a canal of ample dimensions, and quickly returned to the river again.

New water-wheels have lately been set, and comprise a Swain and two Collins turbines. At present, when running at full capacity, 1,200 horse-power is employed, the head on the wheels being about 25 feet. The entire fall, however, on the Ponemah privilege is 30 feet; the wheels have been set for that fall, which will be gained by excavating the shoals in the river below the mill.

The whole privilege, with 30 feet fall, is estimated at 1,500 effective horse-power in a low stage of the river, or sufficient for 115,000 cotton-spindles. In ordinary years full capacity can be run all the time by water, but in exceptional seasons, such as the summers of 1881 and 1882, the supply runs short for perhaps a couple of weeks; in such emergencies a 250 horse-power steam-engine is employed. With the present head the privilege is estimated never to fall below 1,100 effective horse-power, and for six or seven months in the year water wastes over the dam day and night. The pond sets back 2 miles up the river, but is never drawn down far, the policy being to maintain it nearly full, and so preserve the head.

The power next to be described is that at Occum, about 2 miles above Taftville. It is not on the line of any railroad, but is a little more than a mile from Versailles station, on the Providence division, and between 2 and 3 miles from Taft's station, on the Norwich division (*a*) of the New York and New England railroad. It is owned by the Occum Company, of Norwich, which has developed it with the view of leasing power to manufacturers. In 1880 a total of 180 (?) horse-power had thus been disposed of to two concerns—the Totokett cotton-mill and E. S. Farnham. The regular rate for power here is $20 per annum per horse-power. I estimate the available power of the privilege as follows:

Estimate of available power at Occum.

Stage of river.	Drainage area.	Flow per second, average for the 24 hours.(*a*)	Theoretical horse-power.		Effective horse-power utilized in 1880.
	Sq. miles.	*Cubic feet.*	*1 foot fall.*	*14 feet fall.*	
Low water of dry year	464	185	21.0	290	180 (?)
Low water of average year		230	26.1	370	
Available ten months in average year.		300	34.1	480	

a By pondage along the stream the flow and power in low stages would probably be doubled for twelve hours in the day.

The improvements at Occum have been very substantially made. The work on the dam, abutments, bulkheads, and a river wall extending some distance down the west bank, is all of cement masonry. The dam itself is 12 feet thick at the base, 6 feet at the top, and 12 feet high; it is backed by gravel, paved on the slope with large flat stones. Supplementary to this part of the dam, which constitutes a roll-way 300 feet long, is 500 feet of earthen embankment, 20 feet high and 50 feet wide at the base. The apron is planked, and below it are large stones placed on the river bed to break the force of the water and prevent scour. There is a bulkhead, with head-gates, at each end of the dam, the design being to use power on both sides of the river. The mills now built are on the west bank, but any new mill would probably be located on the opposite side. The west canal is about 500 feet long, 40 feet wide, and 8 feet deep. The available fall at the mills is about 14 feet. Above the dam is a pondage estimated at 75 acres.

a Norwich and Worcester railroad—leased.

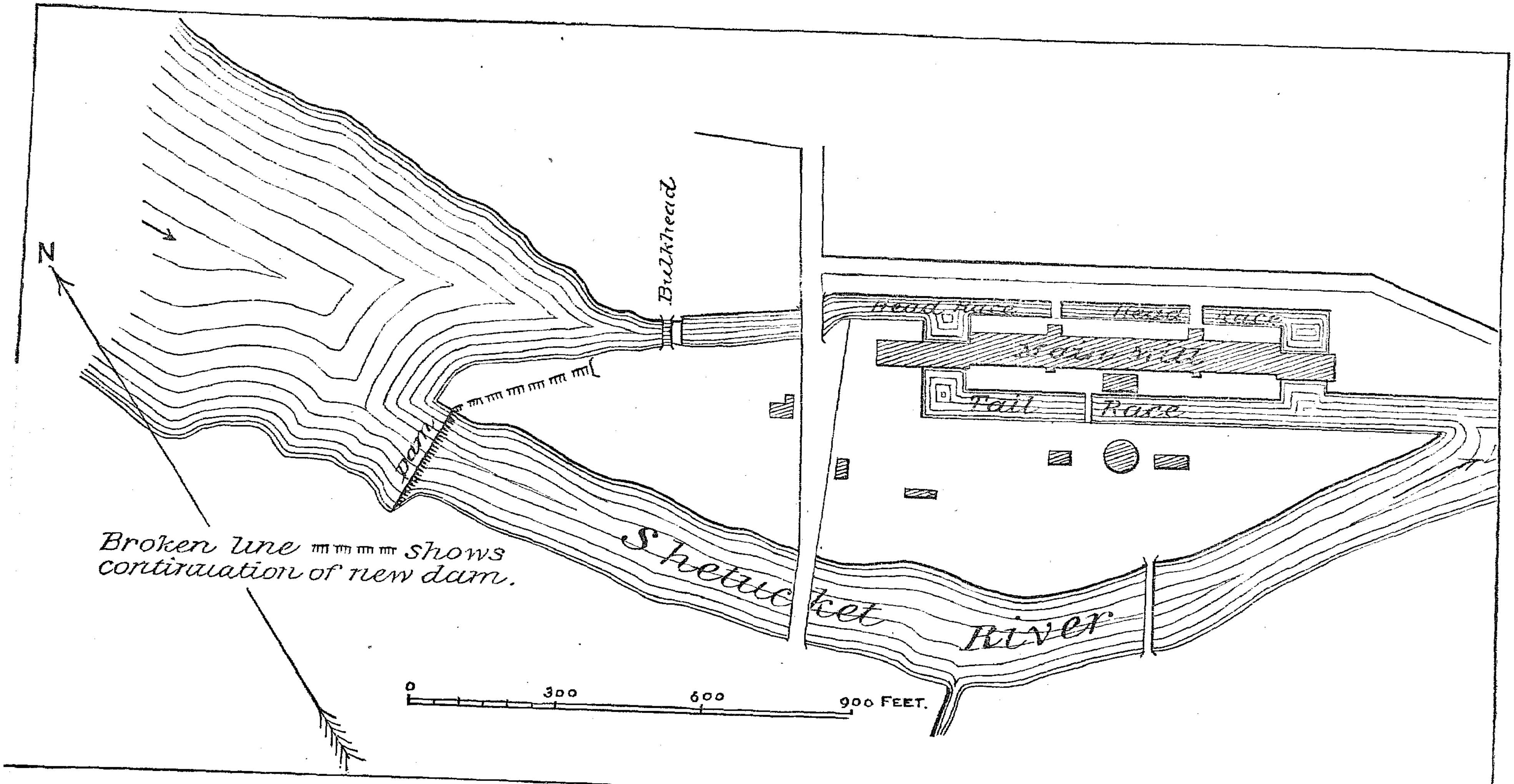

FIG. 6.—Plan of Baltic Privilege previous to the failure of the dam.

The Occum dam cost, in round numbers, $50,000. Work upon it was begun about the year 1865 or 1866. During its construction the company became involved in a lawsuit and was compelled to stop work; and a heavy freshet occurring about that time carried away part of the dam, with a loss of $15,000; and again, at the time of the Baltic disaster, it was damaged to the extent of about $27,000.

The last improved privilege on the Shetucket is the splendid one at Baltic, belonging to the estate of the A. & W. Sprague Manufacturing Company. It is at present leased by H. L. Aldrich, of Providence, for the manufacture of print cloths. The main building of the mill is 630 by 68 feet, and has two wings which increase the total length of the structure to 850 feet; it is 60 feet high and contains four principal stories, or six counting the basement and attic. In all 70,700 spindles are run, and 1,750 looms; 1,100 hands are employed, and when running full capacity, 142 bales of cotton are used per week.

The present dam was built in 1876. It rests upon a gravel bed, and abuts at the west end upon a natural ledge. The roll-way is 515 feet long, with a height of 24 feet above the river bed; it is 80 feet wide at the base and 4 feet wide at the top. The actual height of the dam, however, is much more than 24 feet, for the structure is carried down into the river bed some 20 feet. It consists throughout of a log crib-work, filled in with stone and puddled. The logs of the various courses are pinned together with iron pins. The face of the dam slopes rather more than the back, and is covered with 4-inch hemlock planking. The apron extends horizontally 17 feet from the foot of the slope, rests upon crib-work like that in the dam, and is covered with 8-inch white-oak planking. At the foot of the back slope, and again at the end of the apron, is priming, consisting of round white-oak piles, 8 or 10 inches in diameter, driven with a pile-driver as far down as possible.

Toward the west end the dam is pierced by a penstock, measuring 4 by 5 feet transversely, for drawing down the pond. The dam is obtuse-angled in plan, the apex up-stream. At the east end of the roll-way is a masonry abutment 37 feet 5 inches high from base of foundation, 80 feet long, and built 20 feet wide, of granite. From this abutment there runs a gravel embankment 180 feet long, 150 feet wide at base, 50 feet wide at top, and about 40 feet high, rising 16 feet above the crest of the dam; through its center extends a row of priming, like that already described, and driven down to about the level of the foundation of the roll-way, that is, some 20 feet below the river bed; at that depth hard-pan was struck. The roll-way of the dam is backed with gravel, paved with large flat stones for a considerable distance from the crest. The tendency of the water flowing over the dam is to form powerful eddies beside and against the masonry abutment. To guard against this a timber wall, some 4½ feet in height, has been carried down the front slope of the dam at an interval of, say, 20 feet from the abutment, shutting off the ordinary flow of water over that portion. A crib-work dike has also been extended some distance below the foot of the abutment and in a line with it.

At the inshore end of the embankment is the bulkhead, a fine piece of granite masonry. It is 80 feet long, 35 feet high, 20 feet wide at the base, and 11 feet wide at the top. Water is admitted to the canal through six gate-openings in this bulkhead. The bank adjoining the bulkhead, on the side away from the river, is a fine, sandy gravel, and at that end of the bulkhead priming was driven to a depth of 25 feet.

The head-race extends 700 or 800 feet from the head-gates to the mill, and then along past its whole front, giving a total length of, say, 1,500 to 1,700 feet; it is 50 feet wide, and carries an ordinary depth of 6½ feet of water. The tail-race also extends the whole length of the mill, in the rear, and then on to the river. Both head- and tail-races are walled with stone.

Power is taken from four Collins turbines (two 8 feet, one 5, and one 4½ feet in diameter), aggregating about 1,200 horse-power; these were stated to run under a head of 24 feet. Reliance for power is placed solely in water, steam not being used for that purpose. There has been a lack of water for running at full capacity not more than fourteen days in any one year. In the extreme drought which was being experienced at the time of my visit, in August, 1882, 850 effective horse-power was being realized, and I was informed by Mr. N. R. Gardner, the manager of the mill, that the river was then lower than he had seen it before in twenty years.

By flash-boards (a) the height at the crest of the dam can be increased 2 feet; the flowage is then approximately 500 acres. For four months in the year the water can be entirely ponded during the night; for six months it wastes both night and day. No trouble is encountered at this point from anchor-ice or from cake-ice. The latter, if allowed to form and break up in the canal, would bother at the rack at the entrance to the flume, but this trouble is obviated by a rude frame-work floating on the surface of the canal, dividing it into squares of a few feet on a side, and thus holding the ice.

Failure of the old Baltic dam.—The original dam at Baltic was a framed structure, open underneath. The roll-way was only 220 feet long, the embankment at that time extending to the apex of the angle in the present dam, or 295 feet farther than now. The abutment was of wood, and the bulkhead was also of wood, old and somewhat decayed. During the great freshet of March 26, 1876, a tremendous body of water came pouring down the river, till there was a depth of 15 feet on the roll-way. It finally broke through the bulkhead, filled, overflowed,

a So called in New England, but termed "brackets" in the West. They are boards fastened temporarily upon the crest of a dam, usually to a height of 1 to 3 feet, and designed to insure a larger storage in low water. They also increase the head so long as the pond remains up.

and gouged out the bank of the canal, and rapidly cut away the embankment of the dam, although the roll-way remained intact. The flood swept against the nearer end of the Baltic mill, of which over 90 feet was carried away, together with valuable machinery. An engine-house was destroyed, and the mill-races were filled with sand and gravel. The loss at this point probably exceeded $200,000, and $400,000 were spent in repairs outside of the mill, including a new dam, abutment, bulkhead, and embankment, clearing out the race-ways and lining them with stone walls.

Unimproved privileges.—I have now described all the improved powers on the Shetucket. There remain two privileges, undeveloped, and located, one at Scotland station, also known as the "Waldo privilege", and one at South Windham. Both belong to the estate of the A. & W. Sprague Manufacturing Company. The fall included in these two privileges may be regarded as about 54 feet, which agrees quite closely with the result to be obtained by deducting the fall belonging to the privileges below from the total fall of the river as shown by the survey of 1825. Ex-Governor William Sprague assigns 20 feet to the Waldo privilege and 34 feet to that at South Windham.

The Providence division of the New York and New England railroad follows down the east bank of the river past both privileges, and the New London Northern road also skirts the west bank at South Windham. Between Willimantic and South Windham the immediate valley of the Shetucket is rather narrow, seldom spreading to a greater width than half a mile to a mile. Hills of moderate height rise from the stream, and are succeeded by higher ranges farther back, only visible from an elevated point. The timber has been generally cut away, though quite large patches remain on the steeper slopes and on the summits of the higher hills. The soil is light and sandy or gravelly, and can be of but little value; the land seems to be used mainly for pasturage, but yields considerable grass and some corn and potatoes. From South Windham to Scotland the country is much more thickly wooded than above; much of the way the hills rise abruptly from the river, so that its immediate valley is narrow, with steep slopes.

At Scotland station the river is from 200 to 250 feet wide between banks. The bed is gravelly, and the banks are also gravelly in part, though sandy in places. Opposite the station they are perhaps 12 feet high. A shoal extends from this point a quarter of a mile, more or less, down-stream to Baltic backwater. In the vicinity of the station the ground bordering the river is flat for a considerable distance back on both sides. Near the foot of the shoals the west bank rises to a high, sandy and gravelly bluff, while the east bank sinks still lower than before, and forms low flats on which the ice is thrown out in spring. A quarter to a half mile above the station the hills close in on either side of the river, and give the only opportunity in this vicinity for a high dam. Thence down stream the east bank is favorable for a canal, except that a short distance above the station a brook puts in from the east. Mills would naturally be located on that side, as the ground is suitable and the railroad near at hand.

I found no record of any gaugings on the Shetucket river, but should estimate the power at this privilege as below. The rainfall on the basin of the river is approximately 11 inches in spring, $13\frac{1}{2}$ in summer, 12 in autumn, 11 in winter, and $47\frac{1}{2}$ for the year.

Estimate of power at Scotland station.

Stage of river.	Drainage area.	Flow per second. (*a*)	Theoretical horse-power.	
	Sq. miles.	*Cubic feet.*	1 *foot fall.*	20 *feet fall.*
Low water, dry year	*b* 420	170	19.3	390
Low water, average year		210	23.8	480
Available 10 months, average year		275	31.2	620

a Average for twenty-four hours. In low stages the flow and power would probably be doubled for twelve hours in the day.
b Above Merrick's brook.

At South Windham the river bed is gravelly and covered with cobble-stones. At the road bridge, which crosses at this point, there is quiet water, extending perhaps 1,000 feet still farther down stream, and succeeded by shoals reaching a long way beyond. Above the bridge a high gravel bluff rises from the river on the west side, and there is a similar one on the east side several hundred feet below the bridge; elsewhere the banks are from 10 to 12 feet high above low water, and succeeded by flat or gently sloping ground for some distance back. I was informed by a resident of the village that the design was to locate the dam, if the privilege were ever improved, opposite the upper bluff; if this were done, I should say that an embankment of considerable length would be required on the other side of the river. As regards building and convenience for shipping, the privilege is finely situated, with abundance of room, and two railroads close at hand.

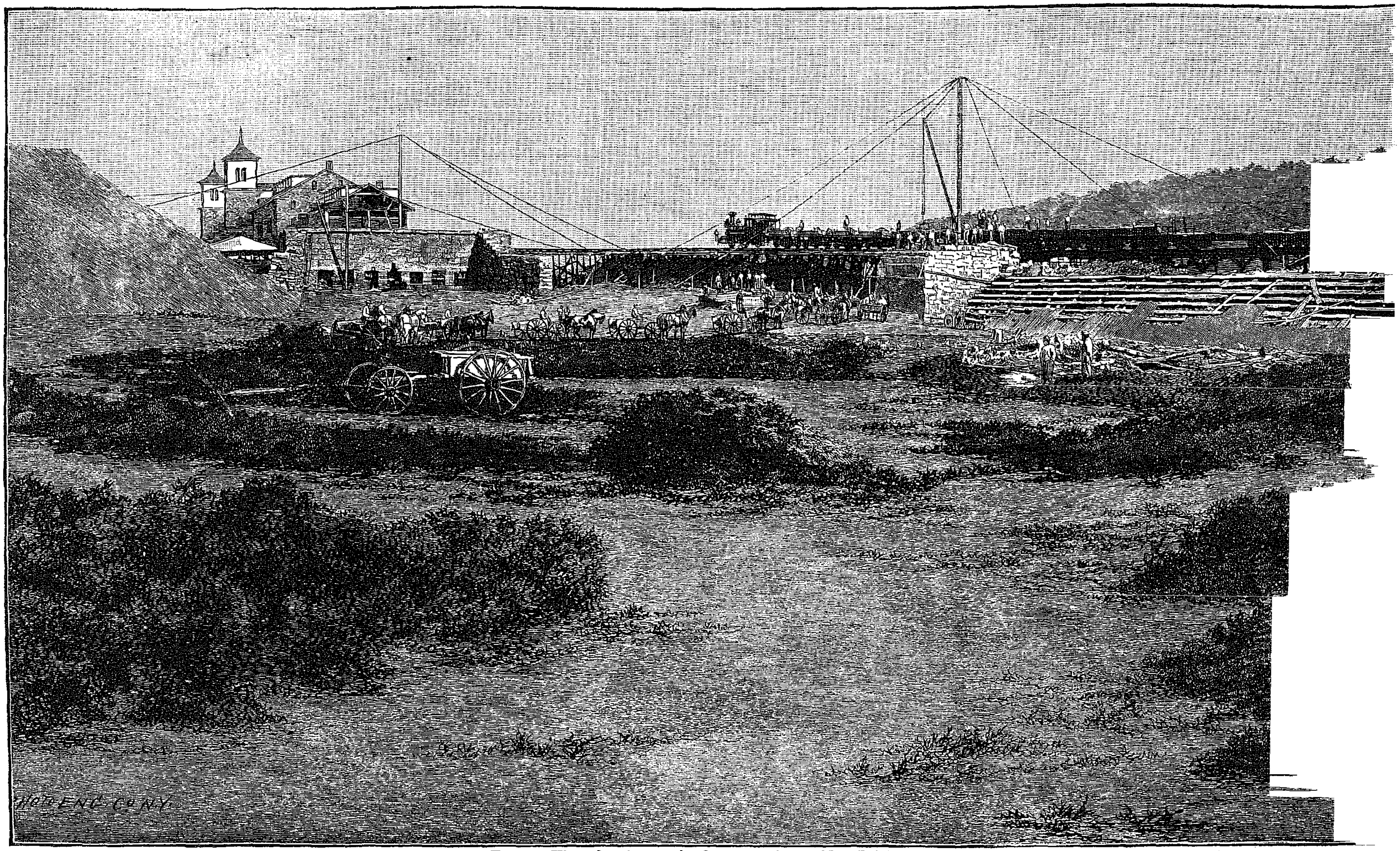

FIG. 7.—View showing work of construction on New Baltic Dam.

Estimate of power at South Windham.

Stage of river.	Approximate drainage area.	Flow per second. (a)	Theoretical horse-power.	
	Sq. miles.	*Cubic feet.*	*1 foot fall.*	*34 feet fall.*
Low water, dry year	400	160	18.2	620
Low water, average year		200	22.7	770
Available 10 months, average year		260	29.5	1,000

a Average for the twenty-four hours. In low stages the flow would probably be concentrated within twelve hours, and, therefore, doubled for that time.

TRIBUTARIES OF THE SHETUCKET RIVER.

THE WILLIMANTIC RIVER.

The main river has a length of 21 miles, measured from its mouth to Stafford Springs; at that point it divides, and in the town of Stafford is made up of several small streams, some of them rising a short distance above the Massachusetts line. Its entire drainage area is 229 square miles. The old survey, previously mentioned, furnishes the only figures I have as to the fall, but it extended only a short distance above the mouth. Some of the localities mentioned in the survey are probably no longer known by the names there given.

Fall in the Lower Willimantic river.

[Survey of 1825.]

Section of river.	Distance.	Fall.
	Rods.	*Ft. In.*
Top Fingley's dam to cove below Lee's tail-race	66	18 9
Thence down the river	54	5 9
Thence to mouth of Byrne & Smith's grist-mill tail-race, including paper-mill fall	208	46 3
Thence to junction with Natchaug (a)	606	87 0
Total, top Fingley's dam to mouth	934	157 9

a Utilized at Willimantic.

In spring there is a heavy run of ice down the river, and gorges sometimes form above Willimantic. The stream is rapid to rise and fall; its drainage slopes are in general steep, underlaid at slight depth by rock, and shed rains quickly. Even in the driest season an ordinary summer shower will start water running over the Willimantic dams. A very high stage of water seldom lasts, however, more than three or four days; for that length of time during the year some trouble is met in the reduction of head, amounting, at the Windham Company's mill, to perhaps one-third of their total fall of 13½ feet.

Willimantic is the principal manufacturing point on the river. The borough contains between 6,000 and 7,000 inhabitants, is finely located, mainly on the right bank of the stream, and has good railroad connections by several lines.

The river is here, where running freely, from 60 to 100 feet wide, and presents very favorable sites for dams. The bed is composed almost entirely of rock ledges, showing a considerable dip to the south and southwest. Where there are no rock ledges the bed is covered with bowlders. The north bank is of good height, steep and rocky; the south bank is less abrupt, and all the mills are on that side. The surface materials in this section are quite variable; there are many ledges of rock, granitic in composition, but with the constituents very coarsely and unevenly mixed. Much of the stone, however, is of better quality, and resembles ordinary granite in general appearance, but is softer, and answers well for building. Most of the stone used for the buildings and dams of the Linen company was obtained either on the premises or close at hand. Bowlders and chips of granite are also found, even deep beneath the surface, and large "pockets" of sand; the Linen company procured sand for building purposes upon its own grounds.

There are six dams across the river at Willimantic, four stone and two framed. The mills are all fine structures of stone, and are located at the ends of the dams, races thus being dispensed with. Far the largest concern is the Willimantic Linen Company, which owns the four lower privileges. Its dams vary in length of roll-way from 125 to 225 feet. Beginning at the lowest, the falls on the successive privileges are 16½ feet, 22 feet, 11 feet, and 13 feet 7 inches. The total rated capacity of water-wheels is 1,150 horse-power, which can be realized about nine months in the year; during the rest of the time steam has to be used more or less. Very little water is ponded at these dams, and the Windham company, farther up stream, is relied upon to hold the water during the night in its pond, which is of good size; this it is able to do for about four months in the year, but for eight months water wastes over the dam, and much of the time both day and night. The Linen company employs 1,500 hands and occupies the following principal buildings: No. 1 mill, part measuring 200 by 72 feet, and the remainder 60 by 80 feet; bleachery, 80 by 112 feet; dye-house, 140 by 70 feet; main mill, 407 by 70 feet; storehouse, 150 by 70 feet; No. 3 mill, 200 by 40 feet; No. 4 mill, 820 by 172 feet (uses 650 horse-power and is run entirely by steam); spool shop, 150 by 40 feet. The sole manufacture is thread, of which 27,000 pounds are made per week, from ninety to one hundred bales of Sea Island cotton being consumed in the same time.

Ascending the river, the next privilege is that occupied by the Smithville Manufacturing Company, manufacturers of cotton sheetings and silesias and running 21,000 spindles. Two wheels, aggregating 300 horse-power, are run under 11 feet head. The company also owns 3 or 4 feet of unimproved fall below the tail-race.

The uppermost privilege at Willimantic is that of the Windham Cotton Manufacturing Company, established in 1822. Eighteen thousand spindles are run in the manufacture of print-cloths. A fall of about 13½ feet is used, with water-wheels of 300 horse-power capacity.

Summary of water-privileges at Willimantic.

Company.	Fall.	Horse-power of wheels.	Remarks.
	Feet.		
Windham Cotton Manufacturing Company.	13½	300	Stone dam, roll-way 147 feet long. For six weeks in low water an average of about 150 effective horse-power is realized.
Smithville Manufacturing Company ...	14–15	300	Eleven feet fall in use. Employs steam-power in addition to water throughout the year.
Willimantic Linen Company (upper privilege).	$13\frac{7}{12}$	270	Stone and cement dam. Steam used as auxiliary power in low water.
Do	11	220	Framed dam with inclined braces. Steam as auxiliary power in low water.
Do........................	22	500	Stone and cement dam. Steam used constantly for auxiliary power.
Do........................	16½	160	Framed dam. Water-power alone used.

Two important storage reservoirs in the Hop River basin are controlled at Willimantic. Columbia reservoir, flowing 282 acres, is controlled by the Linen company. It was formed by raising the water-level to a height of 25 feet above the natural water-surface in the stream at the dam; it will admit of being drawn down 22 feet, but does not fill regularly. Bolton reservoir is owned jointly by the three Willimantic manufacturing companies and the Hop River Warp Company. Its flowage is roughly estimated at 500 acres; it fills regularly, and, it is said, can be drawn down 8 feet from full water-line.

Passing above Willimantic, 13 feet fall and 150 horse-power are used by the Eagle cotton-mill at Eagleville, and at Mansfield and Merrow's Station falls of 10 feet each and small powers are also in use.

From Willimantic to Stafford Springs the country has a hilly surface, diversified by a moderate amount of timber. The immediate valley varies considerably. In some places it is narrow, with steep rocky slopes; in others wider, with a long, gradual rise to the summits of the hills. Narrow strips of grass-land border the stream at intervals, but are reported to be not very valuable. The stream itself is small, with a gravelly bed, and shows many riffles, with now and then stretches of quiet water. Through the intervales the banks are low; elsewhere they are not sharply defined, and are very variable in slope and height. The New London Northern railroad follows the river closely. There is considerable unimproved fall between Willimantic and Stafford Springs which would answer for powers of moderate size. It is mainly in the hands of farmers owning adjoining land, and they are said to be reasonable in their prices and anxious to have improvements made. At points toward Stafford Springs the valley is too narrow to be favorable for canals or buildings, but in the whole stretch of river considered several good privileges could doubtless be obtained.

TRIBUTARIES OF THE WILLIMANTIC RIVER.

Two principal branches, which for convenience may be termed the East and West, unite at Stafford Springs, Connecticut, to make up the main Willimantic river. Below the junction Rawitser Brothers have two small privileges, but the principal manufacturing is on the branches. The East fork has the more rapid fall and is much the flashier stream of the two. The West has a broader valley and carries more water; after a rain it usually continues to rise from six to twelve hours, and then gradually falls. It has two large reservoirs, and above the junction of the streams from Square and Orcuttville ponds there is an extensive wooded section from which one or two well-sustained little brooks proceed that materially assist this branch. Above their confluence the drainage areas of the East and West branches are, respectively, 20 and 36 square miles.

The East branch has a narrow valley much of the way, with steep rocky slopes, and while it continues rising so long as a storm lasts, on its cessation it immediately recedes and soon sinks to its former volume. Five miles above Stafford Springs this branch is supplied by a reservoir owned by the Stafford Water Power Company, an association of mill-owners who hold stock in proportion to the amount of their fall. This reservoir contains 200 acres, and can be, and in some seasons is, drawn down 20 feet below full water-line; it has an extensive water-shed reaching 2 miles or more away, and always fills in spring. For two or three months the reservoir is drawn upon to supply the stream, but for the remaining time the natural flow alone is sufficient.

March 27, 1877, the old reservoir dam gave way, carrying with it all the dams, eight in number, and bridges on the stream below, causing a loss of two lives and a damage estimated at $100,000. The dam had been built under the charge of an experienced man. Work had been carried on, however, through the winter, when the material of the embankment was in a frozen condition; in spring it became soft, and a heavy rain coming on the whole went out.

The dams on this branch are, in Stafford Springs at least, of stone. The ponds are mainly small and are not relied upon for much storage, the flow of water being sufficiently well controlled at the reservoir. The fall seems to be about all taken up. There are mills at intervals all the way up to the reservoir, each mill clustering around it a little village of its operatives. The volume of water flowing in the stream is small, but the heads obtained are large; at the three lower mills, at least, breast and overshot wheels are used. Water is usually brought to the mills through races several hundred feet in length carried along the side-hills. The upper mills have to transfer goods and material to and from Stafford Springs by team. The village has a population of about 2,100, enjoys fair shipping facilities, and has considerable manufacturing importance.

Lower privileges on the East branch at Stafford Springs.

Company.	Fall employed.	Horse-power of wheels.	Remarks.
	Feet.		
Granite Mills	27	80	Lowest privilege. Stone and cement dam; roll-way 100 feet long and 22 feet high, with supplementary embankment 200 feet long. Small pond; race 800 feet long; breast-wheel used, and can generally be run at full capacity throughout the year; steam for auxiliary power.
Warren Woolen Company	25	100	Stone and cement dam about 25 feet high; race say ½ mile long; worsteds manufactured; two overshot wheels and from 20 to 30 horse-power of steam in use.
Glyn Company	19	50-60	Power located rather above the village; company manufactures cotton warps and yarns, employs 25 hands, and runs 2,200 spindles; dry-stone dam with gravel backing, built in 1877 at a cost of $5,000; roll-way 100 feet long, 17 feet high; overshot wheel used.
Riverside Woolen Company	26	84	Two or three miles above village; uses turbine wheel.

The areas of the reservoirs supplying the West branch cannot be definitely given. The Orcuttville reservoir is roughly described as about three-quarters of a mile long by half that breadth, and Square pond as nearly a mile each way. The former is owned by the Orcuttville company, using power at the outlet. It is reported that the company has the right to raise the pond 2 feet higher, and that it would admit of being raised 5 feet. Square pond is a natural lake raised 6 feet by a dam, and can be drawn down 7 or 8 feet. It is owned by Messrs. C. Fox & Co., of Stafford Springs. It is said to be possible to raise this pond 8 feet higher, but the site of the present dam has considerable quicksand, and would hardly admit of a higher dam in safety, without an excavation down to rock. This pond is fed to an important extent by large springs in its bed.

The lowest improved privilege on the West branch is that occupied by the 7-set mill of the Mineral Springs Company, manufacturers of cassimeres. This company has 14 feet head, uses 50 horse-power of water, which can be realized except in very dry seasons, and also employs 75 horse-power of steam.

Wangumbaug lake and outlet.—This lake is a beautiful sheet of water, with a surface variously estimated at from 400 to 600 acres. It lies toward the center of the town of Coventry, Connecticut, and drains easterly by a short outlet to the Willimantic. The drainage area of the lake alone is perhaps 5 square miles, and, including the outlet, not more than 7 square miles. Wangumbaug lake is a natural pond which has been raised by a dam. It can be drawn down 18 feet from high-water line, and for 13 feet below that line has a large flowage; in the remaining 5 feet its bottom shelves in rapidly. It depends largely upon springs in its bed for water, but the supply from all sources is insufficient to meet the demands of manufacturing, and the reservoir has not been full since 1872. It would admit of being raised still further than at present, but such a change would, of course, be useless. When visited, in August, 1882, the lake was furnishing about 500 cubic feet per minute, and was drawn down to within 2 feet of low-water mark. By a decree of court the maximum draught on this lake is limited, under a penalty of $10,000, to 720 cubic feet per minute, equivalent, at an efficiency of 70 per cent., to about 0.96 horse-power per foot fall.

The stream which runs down through the village of South Coventry is entirely dependent upon the lake for its supply. It has a rapid descent of 250 feet, in the 2 miles of its course, from low water in the lake to the Willimantic river, the fall being greatest toward the head. Its course lies through a narrow and beautiful valley, in which there is a succession of manufacturing establishments of small to medium size. The fall is nearly all taken up, but there is one privilege of 12 feet fall unimproved; there are also one of 12 feet and one of 18 feet, improved but unoccupied.

Water-privileges on Wangumbaug outlet (in order from the head).

Occupied by—	Fall.	Manufacture.	Occupied by—	Fall.	Manufacture.
	Feet.			*Feet.*	
White	14	Carriage-spokes.	C. H. Kenyon & Co	13	Flannels (2 sets).
Wood	26	Shoddy.	do	26	Flannels (5 sets).
Tracy	18	Wool extract.	Parker	12	Privilege unoccupied.
Washburne	8	Silk.	Kingsbury	10	Saw-mill and wood-working shop.
Morgan	14	Silk.	Huntington	12	Silk.
Mason	7	Metallic cartridges.	Simpson	10–12	Privilege unoccupied.
Gilboa	30	Woolens (7 sets).	Rawitser Bros	18+	Privilege unoccupied; mill burned.
Wood	30	Woolens (2 sets).			

The eight establishments from Tracy's to Kenyon & Co.'s lower mill use steam as auxiliary power in low water. The time during which a full supply of water can be obtained varies so greatly in different years that no general statement as to its duration can be made. Kenyon & Co.'s experience for a single year was as follows: in 1881, ran by water till September; then shut off water entirely till January, 1882; then had nearly enough water all the time up to August. The ponds along the outlet are of no importance; Kenyon's pond is as large as any but would not supply the mill more than two hours. Teaming has to be done between the mills and the New London Northern railroad at the mouth of the stream; a spur track might, however, it is thought, be run up the valley to the lower mills, and would thus diminish the length of haul.

Hop river joins the Willimantic from the west 3 miles above the Natchaug. It has a drainage area of 50 square miles at Andover, and a total of 75 square miles above its mouth, the area lying entirely in Tolland county. From Hop River station to the mouth, some 3 miles, the immediate valley is rather flat, and the stream usually bordered by a strip of meadow grass-land. Farther back rise hills of good height, moderately timbered with a young growth. The New York and New England railroad follows the river, and is frequently close beside it.

The stream itself is from 50 to 75 feet wide in its lower course, and consists of a succession of rather sluggish pools joined by gravel shoals; in the pools the bed is muddy or sandy, and the adjoining banks are of the latter nature and a few feet in height above low water. The river rises rapidly after rains, and then falls away more gradually; the ordinary freshet-rise at Hop River station is perhaps 4 feet. Although from this point down the benefit is received both of the Columbia and the Bolton reservoirs, previously described, the volume sinks very low in the dry season. It is considered, however, that by raising the level of the Bolton reservoir the capacity of the stream could be substantially increased.

The Willimantic Linen Company owns 20 feet fall, extending up from the mouth, and holds it rather to protect its own water-power interests at Willimantic than for actual development. The only factory on Hop river is that of the Hop River Warp Company, William C. Jillson proprietor, about 3 miles from the mouth; 15 feet fall is used there, and 75 horse-power, which can be realized about nine months in an average year; for the rest of the time not more than from one-half to three-quarters of that amount is obtained.

The Natchaug river.—This stream unites with the Willimantic, to form the Shetucket, somewhat below the borough of Willimantic, and below all the mill privileges there. Its sources are in the towns of Union and Woodstock; its basin includes an area of 171 square miles, lying mainly in the western part of Windham county.

Fall in the lower Natchaug river.

[Survey of 1825.]

Section of river.	Distance.	Fall.	
	Rods.	*Ft.*	*in.*
Top of Swift's dam to foot of falls below mill	22	17	3
Thence down the river	366	12	3
Do	88	3	9
Do	82	3	8
Thence to mouth of river	454	14	8
Total from top of Swift's dam to mouth	1,012	51	7

The Natchaug is used considerably for small manufacturing, but its resources have not been thoroughly developed, and, as will be seen later, its reservoir capacity could be largely increased. One disadvantage to its use for power is that it is not very conveniently reached by any line of railroad. It runs, in its lower course at least, through a hilly country, well wooded, slightly cultivated, and sparsely settled. Its valley is comparatively narrow, and is a succession of intervales, between which the hills approach close to the water. The meadows of these intervales serve as grass-land of rather poor quality.

The fall is moderate, and is mostly made up of shoals, commonly located in the narrows between the intervales, while through the latter the flow is sluggish. The bed is variously composed of ledge rock, loose rocks or bowlders, gravel, mud, and sand, the two latter materials in the sluggish reaches. At Mansfield Hollow the stream falls abruptly over ledges of gneiss rock, which has also been quarried in the banks and used in the construction of a new mill.

At North Windham the Natchaug is 60 or 70 feet wide. The country which it drains seems to be well supplied with springs, and water is readily obtained by wells; nevertheless the stream is at present very unsteady; it rises rapidly, and at times a heavy rain will cause it to overflow the banks in twelve hours. Heavy freshets occur in spring, when the river submerges its banks and sometimes spreads out nearly a mile in width at favorable points, covering the valley from hill to hill. Cake-ice does not commonly cause much damage, still it is often thrown out on the flats in large amounts, and in some places gorges and chokes up the stream.

Near the mouth of the Natchaug the Willimantic Linen Company owns 10 feet of unimproved fall. The first improved power in ascending the river is at Mansfield Hollow, and is occupied by the National Thread Company, which takes skein thread from various factories in Massachusetts and Rhode Island and puts it up ready for market. Goods must be transported 4 miles by team to and from Willimantic, but this is not considered a serious disadvantage, the expense of cartage being not more than 6 or 7 cents per hundred pounds. The river at this point descends in a short distance 17 or 18 feet over rock ledges. At the head of the falls is a curved stone dam, forming a small pond above which would not supply the mill more than three hours. The head actually used is 14 feet, with 60 horse-power of wheels; this amount of power can be obtained throughout some years, while for two months in others not more than half as much can be realized. In the summer of 1882 a fine new stone mill was erected, three stories high, and measuring 155 by 52 feet in plan.

The next privilege is occupied by a small shoddy-mill at North Windham, having a low dam and a few feet fall. A short distance above, Messrs. E. H. Hall & Son have a mill at which they manufacture thread in skeins, though they do not put it up for market. The dam rests on a rock ledge, and is a stone and cement structure with a roll-way 200 feet long. The pond is large, extending a mile up stream, with an estimated average width of 300 feet. A fall of 11 feet is used, and a 60 horse-power wheel, soon to be replaced by one of 93 horse-power. Sixty horse-power can generally be realized nearly all the year; for two months the whole flow of the stream can be ponded at night, while for ten months there is a waste over the dam, and most of that time both night and day.

At Chaplin, 3½ miles above North Windham, there are four dams, with power used by two saw- and grist-mills, a paper-mill, and a pulp-mill. There are also several small mills in Eastford, still farther up stream.

In the lower part of the river there is thought to remain not much available fall. Two miles above North Windham 25 feet could be secured, with a large storage, as will be seen later, and at Chaplin there is 15 feet of fall unimproved. The power at these points may be estimated as below:

Estimate of power available near Chaplin.

Stage of river.	Drainage area.	Flow per second, average for the 24 hours.	Theoretical horse-power.		
	Sq. miles.	*Cubic feet.*	*1 foot fall.*	*15 feet fall.*	*25 feet fall.*
Low water, dry year	70–80	15	1.7	25	40
Low water, average year		25	2.8	40	70
Available 10 months, average year		40	4.5	70	110

Two reservoirs at present supply the Natchaug in the dry season—Crystal lake and Eastford reservoir. The former is a natural pond raised by a low dam, and is controlled by Kenyon Brothers, of Woodstock Valley; it contains 200 acres, and can be drawn down 7 feet. Eastford reservoir flows 200 acres, and can be drawn down 14 feet; it is owned by E. H. Hall & Son, of North Windham, and is sufficient to keep up the supply at their mill for six or eight weeks in low water.

It is said that the reservoir capacity of this river can be substantially increased, and in particular at the localities mentioned below; any improvements of this kind would benefit not only the Natchaug, but the entire course of the Shetucket:

(*a*) In the vicinity of Crystal lake a branch of the main river can be dammed and a large reservoir formed, into which Crystal Lake outlet would empty. It is roughly estimated that the combined flowage of Crystal lake and this new reservoir would be from 1,300 to 1,500 acres—certainly a large amount if realized—and that at least 6 inches of water could be assured at all times on Hall's dam at North Windham.

(*b*) In the northwest part of Chaplin a reservoir of 200 acres could be secured. The combined expense of constructing this and the one near Crystal lake, including flowage and dams, is placed at $30,000 or $40,000.

(*c*) Two miles above North Windham, on the main river, at an expense of not over $2,500, 250 acres could be flowed, with a maximum depth of 25 feet.

OTHER TRIBUTARIES OF THE SHETUCKET ABOVE THE QUINEBAUG.—*Little river* is a small stream joining the Shetucket from the left immediately below the Occum dam, and draining 41 square miles. Its only reservoirs are those formed along its course by dams at which power is used, but it is stated that there are good facilities for storage in its upper waters; at present it does not furnish much power except for a few months in the year.

The first privilege, a short distance above the mouth, is owned by Messrs. L. M. Heery & Co., manufacturers of cassimeres, worsteds, and suitings. They run 16 sets of cards and 5,640 spindles. Wheels are used aggregating about 175 horse-power, with a fall of 15 or 16 feet; these can be run at full capacity four or five months in the year, but during the remainder steam is used as auxiliary power.

Half a mile above, the Reade Paper Company has a pulp-mill, with 12 feet fall and 75 horse-power; and an equal distance still farther up stream a paper-mill, with 21 feet fall and 104 horse-power. During the severe drought of August, 1882, there was being realized, at the upper privilege, 24 horse-power twenty-four hours in the day. There are one or two woolen mills farther up stream, and 5 miles above the power last described the Reade company owns and holds for sale an unoccupied privilege having a good stone dam, 14 feet fall, and two turbine wheels.

THE QUINEBAUG RIVER.

This stream, the most important tributary of the Shetucket, may be said to have its origin in the town of Brimfield, in southern Massachusetts, although it receives there a number of small brooks from adjoining towns. Flowing southeasterly through the towns of Sturbridge, Southbridge, and Dudley, it enters Connecticut, and runs southerly through the eastern part of Windham county; passing into the northern part of New London county, it joins the Shetucket 3 miles above the mouth. It has a length of 49 miles below Southbridge, and a total length of 60 miles measured from the mouth of Mill brook, in the town of Brimfield, to its own mouth. Its drainage area includes 725 square miles. For the fall on this river the only source of information is, again, the old survey which has been referred to in connection with the Shetucket.

Fall in the lower Quinebaug river.

[Survey of 1825.]

Section of river.	Distance.	Fall.	Remarks.
	Rods.	*Ft. In.*	
From top of Danielson's old dam, 4 rods above Killingly bridge, to Pierce's bridge, between Brooklyn and Plainfield.	1,448	52 11	Fall now improved by dams.
Thence down stream to mouth of Packer-and-Lester or Varnum's brook.	2,501	28 8	As nearly as may be estimated, about 3 feet of this, next below Pierce's bridge, is taken up by the Wauregan mill-privilege. With this assumption the fall from the top of the Danielsonville dam, as claimed for the improved privileges, amounts to about 2 feet more than as shown by survey; possibly due to flash-boards or other increase in height of crest of the Danielsonville dam since the time of the survey. Deducting 3 feet, there remains 25 feet 8 inches, constituting what is known as the "Packer" or "Canterbury" privilege, which is unimproved.
Thence down stream to mouth of Pachaug river	1,922	26 3	Unimproved.
Thence down stream to mouth of Morgan's brook	1,171	15 1	The tail-race from Slater's mill on the Pachaug is stated to take up 2 feet 4 inches of this fall; the remainder is unimproved.
Thence down stream to foot of Quinebaug falls	688	38 3	Unimproved.
Thence down the Shetucket river to tide-water at Norwich	850	19 5	Owned and improved by Norwich Water Power Company, which is also said to claim 1 foot more fall.
Total fall from top of Danielson's dam to tide-water in the Shetucket.	8,580	180 7	

Although the descent of the river is moderate, amounting to less than 7 feet per mile for the distance above mentioned, it is sufficient to carry off freshet waters promptly and prevent serious hinderance to the mills from backwater. They all suffer slightly from a temporary reduction of head during freshets, but an extremely high stage seldom lasts more than half a day, and only in rare cases renders necessary a stoppage of work; the Monohansett mill at Putnam has been shut down by backwater only once in ten years. The large number of storage reservoirs and mill-ponds in the Quinebaug basin holds back the water of storms and melting snows, and very much modifies the violence of freshets. The ordinary freshet-rise where the river is running freely, below the dams, throughout the length of the Quinebaug, does not exceed from 3 to 6 feet, and only in extraordinary cases does it amount to 8 or 9 feet. At Wauregan the highest rise in four years previous to 1882 was $5\frac{1}{2}$ feet. Steam is in common use as auxiliary power during periods of low water, at various points both on the Quinebaug and on its tributaries. The necessity for this has not arisen from any inferiority in these streams as compared with streams in general, nor does it seem to be due to a gradual failure of the water-courses from the cutting of timber, but rather to greater demands having been made than the low-water capacity of the streams was calculated to meet. Doubtless the natural dry-season flow, if that could be determined, would be found less now than fifty years ago, owing to the clearing of timber and the drainage of swamps; but that diminution is disguised and has been overcome by the extensive building of storage reservoirs. Although these improvements have been of great benefit in sustaining the streams, mill-owners have gone on adding to the machinery in their mills, and driving it all at greater speed than formerly, until they have outstripped the capacity of their water-privileges for furnishing constant power.

It would be of interest to be able to give a complete list of all the storage reservoirs in the Quinebaug basin, with their areas accurately determined, but the latter, at least, is impracticable; many of the reservoirs are natural ponds which have been raised and whose areas have not been measured. Such maps as could be obtained are rather old, and either do not show many of them at all, or else represent them with areas very different from what they now have. It has been necessary, therefore, to rely in many cases upon estimates of their size; in doing so the best authority has been sought—that of those owning or controlling the reservoirs and presumably familiar with their capacities. The following table presents the results of these inquiries; it may be relied upon as including all the more important storage reservoirs tributary to the Quinebaug, and as giving the areas of most with tolerable accuracy:

Principal storage reservoirs in the Quinebaug basin.

Name.	Locality (town).	Approximate area.	Stream supplied.	Remarks.
		Acres.		
Pachaug reservoir	Griswold, Connecticut	900-1,000	Pachaug river	Entirely artificial.
Beach pond	Eastern part of Voluntown, Connecticut.	1,000-1,200	do	Area estimated.
Billings pond	Northern part of North Stonington, Connecticut.	100	do	
	Plainfield, Connecticut	100	Moosup river	Unoccupied privilege on Moosup river owned by Aldrich, Milner, & Gray; area estimated.
Moosup pond	Northeastern part of Plainfield, Connecticut.	600-700	do	Area estimated.
Oneco pond	Oneco, Connecticut	125	do	Unoccupied privilege.
Nashawang reservoir	On Quinebaug, above Wauregan, Connecticut.	75	Quinebaug river	Area estimated roughly.
Old Killingly pond	Eastern part of Killingly, Connecticut	200	Whitestone brook	Area estimated.
Edy reservoir	Killingly, Connecticut	60	do	Do.
Simmons' reservoir	do	65	do	Area by survey.
Middle reservoir	do	100	do	Area estimated.
Bog Meadow reservoir	do	30	do	Do.
Wakefield pond } Quaddick pond }	Eastern part of Thompson, Connecticut.	1,500	Five-Mile river	Do.
Keach's reservoir			do	
Alexander's pond	Northwestern part of Killingly, Connecticut.	216	Short stream to Quinebaug	Area measured on old state map.
Woodstock pond	Eastern part of Woodstock, Connecticut.	86	Muddy brook	Do.
Hayden pond	Eastern part of Dudley, Massachusetts	93	Small stream emptying into French river and used for power by the Stevens' Linen Works.	Areas by survey.
		25		
Larned pond		34		
Peter pond		44		
Merino pond		83		
Chaubunagungamaug lake	Webster, Massachusetts	1,300	French river	Areas as given by H. N. Slater, esq., president Slater Woolen Company.
Robinson pond	Oxford and Sutton, Massachusetts	100	do	
Sacarap reservoir	Oxford, Massachusetts	125	do	
Charlton or Granite reservoir	Charlton, Massachusetts	240	do	
Pierpont Meadow pond	Northeastern part of Dudley, Massachusetts.	100	do	
Platte pond	Charlton and Oxford, Massachusetts	125	do	
Styles' reservoir		400	do	
Burncoat pond	Western part of Leicester, Massachusetts.	142	do	Area by survey.
Cedar Meadow pond	Leicester and Spencer, Massachusetts	153	do	Do.
Mashapaug pond	Union (northeastern part), Connecticut	225	Upper Quinebaug river	Areas as stated by Hamilton Woolen Company, which controls the reservoirs.
Holland pond	Holland, Massachusettts	445	do	
Cedar pond	Sturbridge, Massachusetts	100	do	
Walker pond	do	100	do	
Hatchet pond		40	do	
Big Alum pond	Northwestern part of Sturbridge, Massachusetts.	200	do	Area by survey.
Little Alum pond	Eastern part of Brimfield, Massachusetts.	73	do	Do.
Long pond	Western part of Sturbridge, Massachusetts.	139	do	Do.
Total		9,443-9,843		Total number of reservoirs in this list, thirty-nine.

It is safe to say that, in round numbers, there are now about forty reservoirs in the basin of the Quinebaug, covering an aggregate surface of 9,000 or 10,000 acres, exclusive of the storage in ordinary mill-ponds along the streams where power is in constant use. Large as this development has become, there is yet opportunity for considerable increase in storage, though mainly in the lower basin. The areas drained by the Pachaug and Moosup still offer favorable sites for extensive reservoirs, but, so far as can be learned, they are the only sections that do offer such sites. The Five-Mile River and Whitestone Brook basins seem to be thoroughly developed as regards storage. It is stated on good authority that there are no opportunities for substantial increase of reservoir capacity about the headwaters of the main Quinebaug. As for French river, H. N. Slater, esq., of Webster, a gentleman probably more familiar than any other with the stream itself and the country it drains, is of opinion that the aggregate capacity of the present reservoirs might be increased 10 or 15 per cent., but that any greater increase, and especially the building of any more reservoirs, is out of the question—they would not fill if built.

DESCRIPTION OF WATER-POWERS.—There is undoubtedly no other locality in extreme southern New England where there is so much well-situated and valuable water-power unimproved as within a dozen miles of Norwich. The two privileges on the Shetucket below Willimantic have already been described, and now, taking up the Quinebaug, there are four valuable undeveloped powers in succession to be noticed as we ascend that stream, before we meet a single one that is improved. Probably it is the very fact that they are large and valuable that has prevented their being taken up for manufacturing purposes. The tributaries of the Thames, and especially the Quinebaug and its affluents, have become established and of great importance as cotton-manufacturing, and, to a less degree, as woolen-manufacturing streams. The development of the privileges alluded to would very likely be for the former industry; but the improvement of such large powers for cotton manufacturing would imply the outlay of a great amount of money, and it is only at considerable intervals that enterprises of such magnitude are undertaken. Nevertheless, it is generally considered that it is the large powers which are most profitably improved, and it is to such that the most attention seems now to be given in New England. It is probably only a question of time as to the development of the fine water-privileges in the vicinity of Norwich; they are now in the hands of wealthy parties who appreciate their value, and who are not disposed to sell except at favorable prices.

From the mouth of the Pachaug to tide-water in the Shetucket there is a fall of 72 feet 9 inches; of this, 2 feet 4 inches are taken up by the tail-race of John F. Slater's mill on the Pachaug; the Norwich Water Power Company covers 19 feet 5 inches, and claims another foot; there remain, then, 50 feet of available unimproved fall between the top of the Greeneville dam and the foot of Slater's tail-race. These 50 feet are divided between what are known as the "Tunnel" and "Bunda Hill" privileges. The latter privilege is owned by the heirs of the late Robert G. Shaw and by Messrs. A. Lockwood Danielson, J. De Forest Danielson, and A. D. Lockwood, the last named gentleman of Providence. The fall is stated to be about 15 feet. The Tunnel privilege is owned by the Shetucket Manufacturing Company, of Norwich, and includes the remainder of the fall, amounting under the above assumptions to 35 feet. Its name comes from the fact of the principal falls being near a short tunnel on the Norwich and Worcester railroad.

Passing up the Quinebaug from the point where it joins the Shetucket, its width quickly contracts and rapids begin. In the lower half-mile there is a descent of 19 feet, and from opposite the tunnel for 1,000 feet, more or less, the river rushes down through a narrow rocky gorge. Along the west bank is the railroad, 25 or 30 feet above the river, and supported by a heavy retaining-wall. The east bank rises with a steep rocky slope from the water, the ascent becoming rather more gentle in the last few hundred feet above the river's mouth. Immediately above the tunnel the stream widens out and a continuous shoal stretches steadily up its course; the east bank now rises more gradually than in the narrows, and appears much more favorable for canal and building improvements. The general character of the stream and its banks then continues without great change up to Jewett City.

The Tunnel power might be improved either as a whole or by dividing it into two privileges. In either case it would be impracticable to build a dam of sufficient height in the narrows, as it would cause overflow of the Norwich and Worcester railroad during freshets. If the privilege were improved in one fall, a dam would have to be located above the narrows and water brought down in a canal; if it were divided, two dams would be required, one above and the other below the narrows. A magnificent power could be obtained by combining in one the entire 50 feet of fall belonging to the Tunnel and Bunda Hill privileges; a dam would have to be located at some point up-stream, and a long canal run down the east bank. A canal of much length would probably encounter considerable ledge rock, especially at the narrows, but much of the material excavated could be used in building the mills. It is considered by good judges that the development of the 50 feet fall in this manner would furnish power sufficient to drive from 250,000 to 300,000 cotton spindles, according to the number of yarn spun, and if it were so utilized would build up a village of 5,000 or 6,000 inhabitants, and add largely to the value of adjoining land. The mills and village would need to be located on the east side of the Quinebaug; they would be within 3 miles of tide-water, but the site has the present disadvantage of being without any railroad, the Norwich and Worcester road lying across the river.

No gaugings of the Quinebaug could be learned of, but the power at these privileges may be estimated as follows:

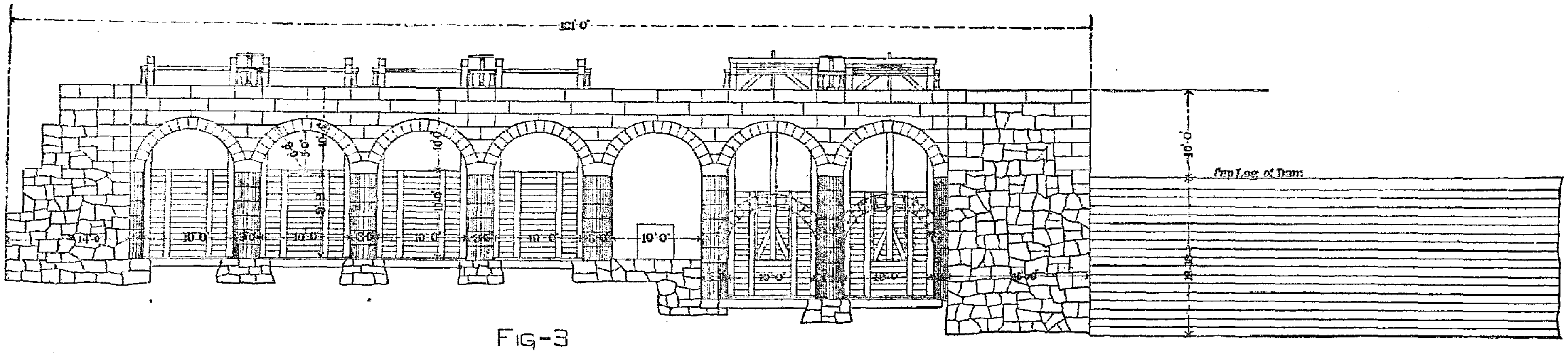

Fig-3

ELEVATION

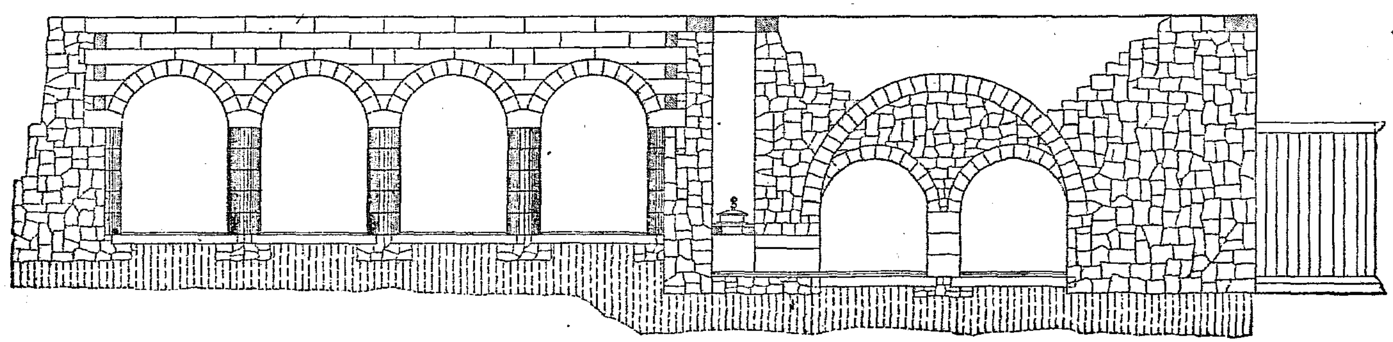

Fig-2

LONGITUDINAL SECTION

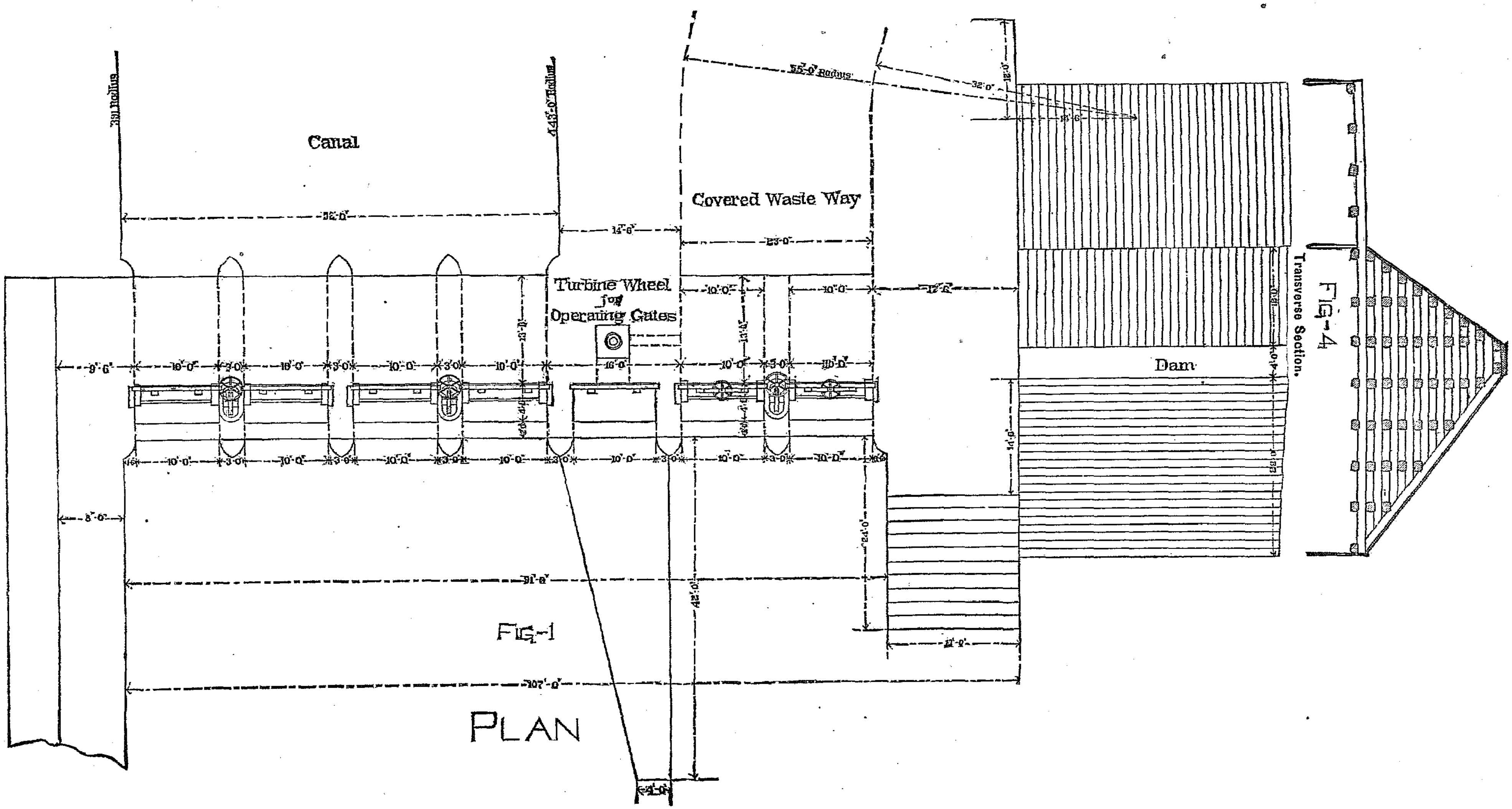

FIG. 9.—Nashawang Water-Power, Wauregan Mills, Plainfield, Connecticut.

Estimate of power at Tunnel and Bunda Hill privileges.

[Bunda Hill assumed at 15 feet, and Tunnel at 35 feet.]

Stage of river.	Drainage area.	Flow per second, average for the 24 hours. (a)	Theoretical horse-power.			
	Sq. miles.	*Cubic feet.*	1 *foot fall.*	15 *feet fall.*	35 *feet fall.*	50 *feet fall.*
Low water, dry year	725	310	35.2	530	1,230	1,760
Low water, average year		360	40.9	610	1,430	2,050
Available 10 months, average year		455	51.7	780	1,810	2,590

a In low stages of the river the flow could probably be doubled for twelve hours in the day.

NOTE.—The rainfall on the basin of the Quinebaug is 11 inches in spring, 12 in summer, 11 in autumn, 11 in winter, and 45 for the year.

The next power on the river is situated at Jewett City, a little way above the mouth of the Pachaug. It is commonly called the "Jewett City" privilege, and is owned by Mr. Charles Johnson, of Norwich. In location and convenience of development it is undoubtedly superior to any other unimproved privilege on the Quinebaug or Shetucket. Jewett City is an old established manufacturing village, with stores, churches, and schools, and contains the extensive cotton-mills of Mr. John F. Slater and the Ashland Cotton Company, run by power from the Pachaug. The Norwich and Worcester Railroad station is less than a quarter of a mile from the falls, and the track runs within a few hundred feet of them. The falls are caused by a chain of partly submerged rocks extending across the river, over which there is an abrupt pitch of a couple of feet; rapids also extend for some distance farther down stream. Above the falls there is smooth water, though apparently with a good current, the adjoining banks wooded and of moderate height. Within 150 feet of the falls the west bank becomes steep, and is perhaps 50 feet high; it continues thus for several hundred feet, past the falls, and then becomes more gentle, the hills receding. The east bank has an easy slope all the way past and below the falls. Where these occur the main channel of the river is probably not more than 100 feet wide; a low rocky island extends a short distance up and down stream, and lies within a few feet of the west shore. Opposite the lower part of the island there rises abruptly on the east shore a mass of ledge rock 10 or 12 feet high above the water, reaching 75 feet along the stream and 25 feet inshore. Inside of this ledge a rocky slope with a scanty covering of soil ascends gradually, as if from the water's edge.

Mr. Johnson's privilege is stated to embrace an entire fall of about 23½ feet. The natural plan of development would be to construct a dam say 18 feet high at the crest of the falls, and carry a short race down the east bank, where there is abundant building room, with the railroad close at hand. The site for the dam offers perfectly secure foundations of solid rock; it is estimated that a substantial timber structure, 18 feet high and 300 feet long, could be built for from \$25,000 to \$30,000. It would set the river back for 4 or 5 miles above, and provide a pondage, as claimed, of about 500 acres. The privilege is rated as sufficient in power to drive 90,000 spindles, No. 30 yarn. My own estimate of the available power in different stages of river is shown below:

Estimate of power at Jewett City privilege.

Stage of river.	Drainage area.	Flow per second, average for the 24 hours. (a)	Theoretical horse-power.			
	Sq. miles.	*Cubic feet.*	1 *foot fall.*	18 *feet fall*	23½ *feet fall.*	26½ *feet fall.* (b)
Low water, dry year	635	240	27.3	490	640	720
Low water, average year		290	32.9	590	770	860
Available 10 months, average year		370	42.0	760	990	1,100

a In low stages of the river the flow could probably be doubled for twelve hours in the day.
b Total unimproved fall in river from mouth of Varnum's brook to mouth of Pachaug.

The last of the unimproved powers which have been alluded to as lying within the vicinity of Norwich is known as the "Packer" and also as the "Canterbury" privilege. It is situated between the towns of Plainfield and Canterbury, extending from the mouth of Varnum's brook to the tail-race of the Wauregan mill, and is variously stated to include from about 26 to a little over 30 feet fall; if we allow 3 feet below Pierce's bridge to the Wauregan privilege, there remains, according to the survey of 1825, 25 feet 8 inches of fall to the Canterbury privilege. It is a good power, but much less favorably located than that at Jewett City, the railroad being farther away and there being only a few scattered farm-houses near at hand. The present owners are Messrs. E. A. & Daniel Packer and William A. Healy, the latter of Hartford.

Estimate of power at Canterbury privilege.

Stage of river.	Drainage area.	Flow per second, average for the 24 hours (a)	Theoretical horse-power.	
			1 foot fall.	25.7 feet fall.
	Sq. miles.	*Cubic feet.*		
Low water, dry year	590	225	25.6	668
Low water, average year		270	30.7	790
Available 10 months, average year		340	38.6	990

a In low stages of the river the flow could probably be doubled for 12 hours in the day.

At Wauregan, 21 miles by railroad above Norwich, is met the first power in use on the Quinebaug river. It is occupied by the Wauregan Mills, running 56,000 spindles in the manufacture of sheetings and fancy cotton goods. The dam was originally built in 1853, but was rebuilt in 1876, and its cost is stated at $27,000. The roll-way is 350 feet long, and consists of a log crib-work filled in with loose stone. The logs are 5 or 6 feet apart, from center to center, in both directions; two or three of the lower courses are set down into the river-bed, and all are carefully fastened together with iron pins. The ends of the logs are adzed to give flat bearings. Priming, or sheet-piling, is driven into the river-bed at the foot of the front and back slopes and at the end of the apron, to prevent water from working under the dam. The top of the structure has a width of 4 feet, and is perhaps 16 feet above the river-bed. The back slope has a base of 21 feet and the front slope a base of 11 feet, making the width at base of the main portion of the dam 36 feet. The face and top are covered with 4-inch oak planking and the back slope is covered with 3-inch chestnut. An apron projects down-stream 23 feet from the foot of the front slope, and consists of 5-inch oak planking, covered part of the distance with a less permanent layer of planking 2 inches thick; this is designed to receive the impact of overfalling ice, and when worn out can easily be renewed. The river-bed here is gravelly.

From the dam a canal, say 1,000 feet long, 50 feet wide, and 7 or 8 feet deep, conveys water to the mill, where it is used under 17 feet head, with wheels of about 900 horse-power. For a month or six weeks in the year there is a shortage of water, during which an average of about 700 horse-power is realized. The pondage is sufficient to control the low-water flow of the stream, and there is very little waste over the dam in summer; during that season the pond is usually drawn down 8 or 10 inches through the day, and fills again at night.

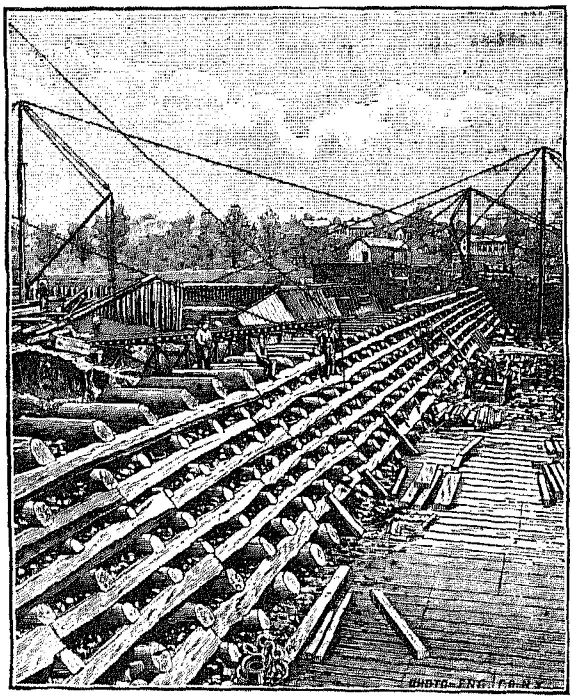

FIG. 8.—New Wauregan dam on the Quinebaug river, during construction.

Immediately succeeding this privilege, and distant 2½ or 3 miles from Wauregan, is the upper privilege owned by the same company. It is called the "Nashawaug" power, and is at present used only for storage purposes; it is held, however, to meet the future needs of the company, and is in condition, with completed dam and suitable gates, for use in manufacturing at any time. The fall covered by this privilege is 17 feet. The dam has a roll-way of about 350 feet, and in cross-section and general construction is a close copy of the one at Wauregan. The width at base of the dam proper is about 37½ feet, and the crest is 16 or 17 feet above the upper surface of the apron; the latter projects 20 feet from the front slope, instead of 23 feet as at Wauregan. The abutment next the bulkhead is 17½ feet wide, at right angles to the stream, and is of granite masonry. The bulkhead is built of granite ashlars backed with rubble in cement, and has a length in the clear, between the abutment of the dam and the shore-wall, of 88 feet. In this distance there are seven arched openings, each 10 feet in width, and separated by piers 3 feet thick; the two openings next the river connect with a covered waste-way, the third is to supply a turbine for operating the gates, and the remaining four are for the purpose of admitting water to the canal. The Nashawaug power is a fine one, and the dam and connecting works have certainly been built in a very substantial manner.(a)

The next power is at Danielsonville, a thriving borough of about 3,100 inhabitants, 27 miles by river and about the same by railroad from Norwich. Cotton manufacturing is carried on here both on the Quinebaug and on Five-Mile river. On the former stream the Quinebaug Company has a fall of 24 feet, and uses a total of 935 horse-power at two mills; the wheel capacity, however, is stated at probably 1,200 horse-power, being large enough to

a Drawings of the dam and bulkhead were kindly furnished by Messrs. Thompson and Nagle, engineers, of Providence.

insure power during a reduction of head by high water. This privilege receives the benefit of the water used from Five-Mile river by the Danielsonville Cotton Company, whose tail-race discharges above the Quinebaug Company's dam. The latter company experiences considerable trouble in winter from anchor-ice. Its canal is 600 or 800 feet long, rather shallow, and has a stony bottom. During the winter season a man is sometimes required for two or three hours every morning, for a period of three or four weeks at a time, to rake the ice away from the racks at the entrances to the flumes. The difficulty disappears as soon as the water-surface becomes solidly frozen over. The Quinebaug Company manufactures cotton sheetings and runs 51,500 spindles. The supply of water is sufficient during all but about two weeks in the year. In the summer of 1882 steam was being introduced into the old mill for auxiliary power in low water; this mill stands intermediate on the line of the canal, and has but 14 feet head.

Three and one-half miles, by river, above Danielsonville, the Williamsville Manufacturing Company, running 550 looms in the manufacture of cotton goods, uses a fall of 9½ feet. This company also owns an unimproved privilege, perhaps a mile and a half above, which was used by a saw-mill many years ago, and some of the timbers of the old dam are still visible. The fall belonging to this privilege was not ascertained.

The next manufacturing place is Putnam, one of the most important points on the Quinebaug, and located at the junction of the Norwich and Worcester (*a*) and main line of the New York and New England railroads. There are three fine powers here, all largely used. The lowest in order covers a fall of 32 feet 10 inches. It was originally owned entirely by Thomas Harris, of Providence. Mr. Harris has sold one-half the privilege to the Putnam Woolen Company, one-quarter has been leased to the Monohansett Company, and one-quarter still remains available for other manufacturing. A three-story wooden building, 104 by 54 feet in plan, provided with a 164 horse-power wheel, and adapted to manufacturing purposes, has been erected but not yet occupied, and Mr. Harris is prepared to put up other suitable buildings for those wishing to obtain power.

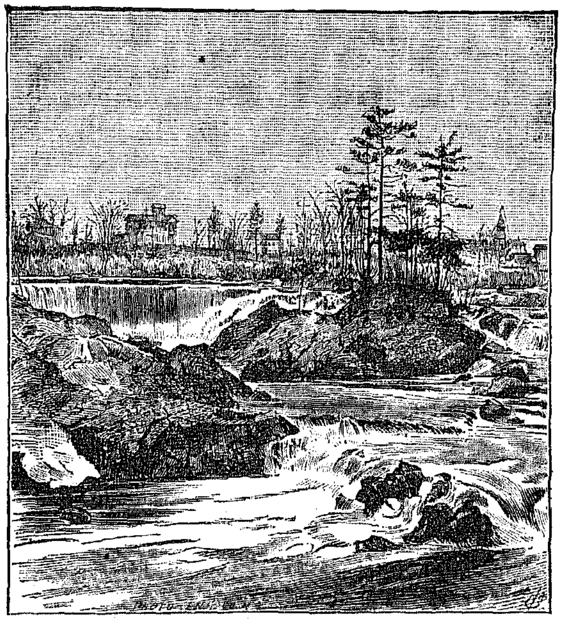

FIG. 10.—Falls in the Quinebaug river at Putnam.

The dam at this privilege is largely natural, consisting of huge ledges which almost choke up the stream, and which are connected by short lengths of framed work. On the west bank are the large mills of the Putnam Woolen Company, while on the east bank a race probably 1,000 feet or more in length conveys water to the mill of the Monohansett Company, manufacturers of cotton goods. The entire privilege is estimated at about 800 effective horse-power in ordinary low water. It is dependent in the dry season upon the running of the mills above, as the pondage here amounts to but a few acres.

The middle privilege at Putnam includes 18 feet fall, of which only 16½ feet has been developed. The dam is a stone and cement structure, with a roll-way 157 feet long, 18 feet high, 22 feet wide at base and 8 feet at top; it was built in 1861, at a cost of about $10,000. Power is used on the east side by the Nightingale mills, cotton goods, 13,000 spindles, 160 horse-power, and on the west side by the Morse mills, cotton-goods, 13,000 spindles, 160 horse-power.

The upper privilege at Putnam is occupied on the east side by the Powhatan mills, running 20,000 spindles on cotton goods, with 15½ feet head and 200 horse-power; on the opposite side is the Putnam Manufacturing Company, cotton goods, with the same head and about the same power. Each concern owns one-half the privilege. The dam is built of stone in cement, with roll-way 115 feet long and 10 feet high; in the face are two arched openings with gates for drawing down the pond. The mills are able to run at full capacity by water about eight months in the year, and from two-thirds to three-quarters capacity the remainder of the time, during which they use steam in addition to water. The pondage above the dam is small, and water wastes at night nearly all the year. The large amount of water used at Southbridge reaches this privilege in the middle of the day, and, there being but small storage facilities here, continues to waste over the dam much of the night. It is thought that upon the completion of the new reservoir at Mechanicsville this water will be saved and the power at Putnam substantially increased. The experience with anchor-ice at this point is worth noticing. The Powhatan mill receives water from the pond directly into its flume, while the Putnam company often draws through an old race; the former mill suffers little or none from ice, but the latter is much hindered and requires considerable labor in clearing its race.

Slackwater from the privilege just described extends to a small place called Reedville, a short distance above the mouth of French river. Here Messrs. Sayles & Washburn, who already have a mill at the mouth of French river, on the latter stream, have recently constructed a dam which will pond a large surface of water, roughly

a Leased to the New York and New England railroad, and denominated by it the "Norwich division".

estimated at 450 acres; this privilege has been developed for their own use, and will probably be employed to furnish power to a new mill. The pond will be connected by a cross-cut with the pond above their dam on French river, and the two privileges can thus be operated so as to be of mutual assistance.

At the site of the new dam the river-bed is gravel, with some quicksand. The dam was carried down 3 or 4 feet below the surface of the apron into the river-bed, and protected by sheet-piling in the usual manner. The roll-way is 200 feet long, rises 15 feet above the apron, is 4 feet wide on top, 30 feet wide at the base, and has front and back slopes of 20 feet each. The back slope is covered with 2½-inch, the top with 4-inch, and the face with 3-inch chestnut planking. In interior construction the dam is a log crib-work filled with stone. An apron projects 16 feet beyond the foot of the dam, and has a permanent covering of 4-inch chestnut plank, over which is a temporary layer of 2-inch white-oak plank, easily renewed when worn out. From the roll-way there extends a gravel embankment 900 feet long, about 20 feet high, 60 feet wide at the base and 24 feet at the top, the inner slope of which will be riprapped. At the farther end of the embankment is the bulkhead, with gates opening into the race.

Above the mouth of French river the Quinebaug has considerably less water than below, but still furnishes important powers, which are used at numerous points. I shall not describe them in detail, but more or less information regarding them may be obtained from the following table:

Utilized powers on the upper Quinebaug river.

[Reedville to Southbridge (in order, ascending the river).]

Locality (town).	Occupied by—	Fall.	Horse-power of wheels.	Remarks.
		Feet.		
New Boston, Connecticut	G. T. Murdock & Son	9½	100–110	Woolen goods, 5 sets of cards. Water nearly always wasting on dam.
Dudley, Massachusetts	E. S. Stevens	12	110	Manufactures gunny-cloth. Small power also used by a 1-run grist-mill. Stone dam; roll-way, 230 feet long; pondage, 40–45 acres. Mr. Stevens owns 6 feet of fall below his privilege.
West Dudley, Massachusetts	Warren Paper Mill	12¾	112	Small power also used by Wells' grist-mill. Perhaps 50 horse-power surplus for rental.
Saundersdale, Massachusetts	Southbridge Print Works	14½	285	
Southbridge, Massachusetts	Columbia Mills	....	....	Print-cloths. Not running.
Do	American Optical Works	7½	35	
Do	Central Mills Company	37	280	Cotton goods, 11,000 spindles. No lack of water; always waste over dam at night. Two falls of 15 and 22 feet, respectively.
Do	Hamilton Woolen Company	54	800	Manufactures cotton goods, cassimeres, and worsted dress goods. Steam used in addition to water. Privileges improved by stone dams, with gravel backing, and priming above and below. Power taken from three falls of 14, 26, and 14 feet, respectively. About 650 horse-power actually used.

Southbridge, at which, as may be seen from the table, several important concerns are located, is a beautiful village and of considerable size; it is built upon hilly ground, with fine streets, and with the usual advantages of a prosperous and established manufacturing village. It has but one railroad, and at times freights have been so high that the Hamilton Woolen Company shipped by team to Charlton, on the Boston and Albany railroad; at present, however, rates on staple articles, such as cotton and wool, are claimed to be as favorable as those enjoyed by Lawrence or Lowell.

The Hamilton company owns five reservoirs, supplying the river above Southbridge; they contain an aggregate area of over 900 acres, and usually fill. The Fiskdale Mills, situated above on the stream in the town of Sturbridge, also own three reservoirs, known as Big Alum, Little Alum, and Long ponds; these have a combined flowage of about 412 acres and a storage capacity of 200,000,000 cubic feet.

The country along the Quinebaug from Reedville to Southbridge is hilly and moderately timbered. There is in this distance unimproved fall belonging to the various farmers whose land adjoins the stream; no data could be obtained showing the total amount of this fall, but several privileges were learned of, as follows:

1. Immediately below E. S. Stevens' privilege (which is really situated just above the Massachusetts line, though the post-office is Quinebaug, Connecticut). That gentleman owns 6 feet of fall, and there is estimated to be several feet more thence to Murdock's privilege; altogether there may be 10 feet.

2. Between Stevens' privilege and that at West Dudley there is 18 feet 4 inches of unimproved fall; of this Mr. Stevens owns 8 feet, and holds it for future use in connection with his business, leaving say 10 feet available for other manufacturing.

3. Between West Dudley and Saundersdale there is 9 feet 7 inches of unimproved fall, owned by Mr. Charles Wells, of the former place. A dam could be built near the foot of this privilege, convenient to the railroad, and would flow about 9 acres.

4 and 5. At Southbridge the Hamilton Woolen Company owns two undeveloped falls, one of 13 and the other of 30 feet.

The power at these several privileges may be estimated as in the accompanying table:

Estimate of power at unimproved privileges between Reedville and Southbridge.

Locality.	Drainage area.	Fall.	Theoretical horse-power. (a)		
			Low water, dry year.	Low water, average year.	Ten months, average year.
	Sq. miles.	*Feet.*			
Southbridge	100	30	150	170	200
		13	65	75	90
Between West Dudley and Saundersdale.		9.6	60	70	90
Below West Dudley		10	70	75	95
Below E. S. Stevens' privilege	145	10	75	80	100

a Based on average flow for the twenty-four hours. The power could probably be doubled for twelve hours in low stages.

TRIBUTARIES OF THE QUINEBAUG RIVER.

Pachaug river.—This properly has its source in four small head-streams which unite a short distance above the village of Voluntown, in the southeastern corner of Windham county, Connecticut. The river then pursues an irregular course to the westward, passing across the town of Griswold, and joins the Quinebaug at Jewett City. It drains 59 square miles, and toward the mouth, where running freely, does not measure probably more than 50 feet across. The valley is wide, and though there are many steep slopes, yet in the vicinity of the Pachaug reservoir there is, on the whole, a gradual rise in nearly every direction to the summits of distant high hills. The country is moderately wooded, the proportion of timber increasing away from the Quinebaug and toward the summits of the hills. The covering of soil is thin, and rock ledges and drift bowlders crop out in all directions. There is comparatively little cultivation, and that chiefly in corn, potatoes, rye, oats, and buckwheat.

The powers, in order, ascending the stream, are as follows:

1. Near the mouth are John F. Slater's mills, running 20,000 spindles in the manufacture of denims, ticks, and other goods. The privilege embraces a total fall of 37½ feet, used in two falls of 15 and 22½ feet, respectively; 400 horse-power is employed at these mills, and a small grist-mill is also supplied by a side-cut from the upper fall.

2. The Ashland Cotton Company uses a fall of 18 feet 9 inches, and 275 horse-power. It has two mills, one an extremely large and fine structure, and runs about 25,000 spindles; during 1881 and 1882 it increased the capacity of its mills 30 per cent. The dam was built in 1858, and was recently raised a foot; it is 75 feet long, 19 feet high, and secures a pondage above of 100 acres.

3. At Hopeville, a couple of miles above the mouth, there is a dam giving 14 feet fall, and surveys have been made with reference to raising it 7 feet, and thus forming a pond extending back nearly to the foot of the Pachaug Reservoir dam. The Ashland company owns this privilege, and formerly had mills here, which were burned; it intends to erect new mills, however, and to use the power.

4. At Pachaug Reservoir dam there is a fall of 12 or 13 feet not in use. This, and in fact all the fall on the stream below, down to Slater's mills, belongs to the Ashland company, which also owns the adjoining land in that distance.

A summary may be given of the above and the remaining powers on this river, as in the following table:

Water-privileges on the Pachaug river (in order from the mouth.)

Occupied by—	Fall.	Horse-power utilized.	Remarks.
	Feet.		
John F. Slater	37½	400	Two falls, 15 and 22½ feet.
Ashland Cotton Company	18¾	275	
Do	21		Power not used. Dam gives 14 feet fall, but can be raised 7 feet. Located at Hopeville.
Do	12–13		Pachaug Reservoir dam. Power not used.
Glasgow Yarn Company	24		
L. W. Carroll	18½	175	Cotton prints.
Ira G. Briggs & Co	15	100	Briggs & Co. manufacture twilled cotton goods and yarns, and run a total of about 15,000 spindles at all the privileges.
Do	22	50	
Do	11	70	
Do	15	100	

Above Briggs & Co.'s upper dam there is a pond of 40 or 50 acres. There have been specified all the powers on the Pachaug up to this point. Everything is in use except at Hopeville and at Pachaug reservoir, and those privileges being reserved by the Ashland company, are not open for general manufacturing. Above Voluntown, on the small streams which have been alluded to as making up the main river, there are some small saw-mills, but the powers cannot be considered as having much value. The fall of these streams is said to be small, and even if reservoired as hereafter described, the reservoirs would be in their lower courses, leaving little fall below.

The most interesting feature of the Pachaug is its reservoir development. Although the stream has considerable fall, there are occasional wide stretches along its course of low marshy ground which have given opportunity for a large flowage. Aside from the regular mill-privileges, the principal of which have been mentioned, there are at the present the following reservoirs on the stream:

Pachaug reservoir is entirely artificial, and contains from 900 to 1,000 acres, according to the stage of water. It is formed by an embankment and dam having a combined length of about 600 feet. The overflow is 80 feet long, and is a framed timber structure, with a partial filling of loose stone, masonry abutments, and an apron. This reservoir can be drawn down 12½ feet, and gives a large storage; it is owned by the Ashland company.

Billings Pond reservoir, covering say 100 acres, lies among the hills, is fed almost entirely by springs, and empties by a small side stream into the upper part of Pachaug reservoir; it also is owned by the Ashland company. Mr. J. O. Sweet, superintendent of the company, who furnished much information regarding the Pachaug, mentions an interesting fact about this reservoir. He states that all evidence has shown that by maintaining it full its total yield is diminished, and explains it by supposing that when full the great pressure of the water forces the springs to seek outlets in some direction other than into the reservoir. The pond is therefore drawn down early in the season, and the gates are then left open, so that the natural flow of the stream goes on.

Beach pond, in the upper waters of one of the four head-streams, is estimated to contain from 1,000 to 1,200 acres, and is a natural lake which has been raised by a dam some 300 feet long, at the outlet. It is very deep, and though it can be drawn down 12 feet there then remains a depth of 50 feet in portions. This reservoir is controlled by Messrs. Ira G. Briggs & Co.

The effect of these large reservoirs is to render the stream very steady. Neither the Ashland nor Slater's mills have been forced to stop more than a day and a half in sixteen years from lack of water, but, as previously stated, the capacity of the former mills having recently been increased 30 per cent., there is some question as to whether they may not now run short at times. The river is also freed from the effects of heavy freshets. In the lower course there is a freshet depth on the Ashland dam of only about 18 inches, whereas, before the stream was so well reservoired, it amounted to many feet. About the year 1862 the dam at Beach pond gave way, and a large volume of water came pouring down stream; but striking into the marshes where the Pachaug reservoir now is, it spread out and caused no harm at Jewett City, neither was there much of a rise there.

The Ashland company practices great economy in the use of the stored water which it controls. It is connected by telephone with the house of the gate-keeper at Pachaug reservoir, and is thus enabled to regulate the flow very carefully. The gates are opened in the morning some hours before the time for starting the mills, in order that the water may have time to reach them, and are closed some hours before the mills shut down. The water is thus maintained just even with the top of the dam at Jewett City, without allowing waste over its crest.

Though the Pachaug is already so well reservoired, there is yet opportunity considerably to increase its capacity in this respect. Messrs. Ira G. Briggs & Co. state that shortly above their upper privilege at Voluntown, between it and Beach pond, there is a chance to flow 1,000 acres by a dam 10 feet high. On the remaining three streams which go to make up the Pachaug at this point, storage reservoirs of fair size can be constructed on their lower courses, the land being rather low and marshy. On one of these streams a survey has shown that a dam 20 feet high would flow 150 acres to an average depth of 10½ feet, and Mr. Briggs is of opinion that about the same flowage would be obtained on the other two. The dam at Hopeville, also, if raised 7 feet, would give a largely increased storage there.

Moosup river.—This stream has its source in the town of Foster, Rhode Island, 2 or 3 miles east of the Connecticut boundary. It runs southerly and then westerly, passing through the towns of Foster and Coventry, Rhode Island, and the towns of Sterling and Plainfield, Connecticut; its total length is about 18 miles, and its drainage area 83 square miles. Its valley is not unlike that of the Pachaug, but perhaps shows less outcropping rock. The hills are high and frequently steep, but they appear, as a rule, to have long slopes. The country has little value for agriculture, and has been mainly cleared of timber, except toward the summits of the high hills or away from the more immediate valley of the Quinebaug. The soil is described as rather shallow, but underlaid nearly everywhere by clay, so that water is easily obtained in wells both on the hills and in the valleys. The water-shed is quite extensive, and the hill-slopes are sufficiently inclined so that water from rains drains rapidly into the stream and raises it, after which it quickly subsides. The greatest height is usually reached about twelve hours after a storm, the freshet rise in the lower course amounting to about 6 feet below the dams. No difficulty is experienced on this river from anchor-ice; cake-ice sometimes piles up on the flats, and even to some extent chokes up the stream, but no serious trouble ensues. In its lower course the Moosup is from 75 to 100 feet wide. Its bed is mainly drift, gravel, and small bowlders. The banks are irregular and poorly defined, sometimes rising abruptly from the stream, and again low, with a gradual ascent.

The principal reservoir supplying this stream is Moosup pond, a natural lake raised by a low embankment. It lies immediately surrounded by hills of moderate height, and empties by a small outlet into Snake Meadow brook, and thence into the Moosup; it is distant a half or three-quarters of a mile, in a direct line, from the latter stream, and is a fine reservoir. The surface is estimated at 600 or 700 acres, which is perhaps too high, and the pond can be drawn down 6½ feet. Messrs. Aldrich & Milner control this reservoir, but if they have occasion to shut down their mill on the Moosup they are under obligations, for the benefit of the Aldrich & Gray mill below, so to manage the reservoir as to maintain the same flow as before.

Above the stone dam at Almyville there is a pond estimated to contain 100 acres, and at Oneco one of 125 acres; these are at privileges available for manufacturing, but not in use, and at present serve only for storage.

The amount of storage on the stream can yet be very largely increased. Aldrich & Milner intend to raise the stone dam at their reservoir (Almyville), and will thereby increase its flowage, as they estimate, by 250 or 300 acres. Thence to Greene the valley is regarded as favorable for storage, and toward the headwaters, in Rhode Island, the facilities are still better; there is much low land in that section, having little value, which might easily be flowed. The amount of storage thus available in that locality is variously stated at from 1,000 to 3,000 acres, but is large at all events.

There have been numerous changes in the firms manufacturing on this river, and many of the present concerns are new-comers. The mills are of fair size, and are in many cases built of stone, which is claimed to be cheaper here than brick for building. Nearly all have engines for use in low water. The stream is said to have decreased in value of late years. The only explanation given of this was, that a number of small privileges on the upper course, previously used for saw and other small mills, had been abandoned; these had formerly stored considerable water above their dams, but the latter had gone to ruin, and, the storage being lost, the stream became more unsteady.

Water-privileges in use on the Moosup river (in order from the mouth).

Occupied by—	Fall.	Horse-power utilized.	Remarks.
	Feet.		
....	9	100 (?)	Henry Cutler owns one-half the privilege and E. N. Tourtelotte one-half. Log dam, 120 feet long. Power used by several small establishments, comprising a wick-mill, twine-mill, grist-mill, saw-mill, and carpenter's shop.
....	4	35 (?)	Log dam, about 100 feet long. Power owned by J. P. Kingsley, of Canterbury, and leased to a small grist-mill and carriage-shop.
Kirk Mills	14	125	Plain cotton goods. Old and cheap log dam. Short of water three or four weeks in some years.
Do	9½	90	Fancy cotton goods.
Aldrich & Gray	21	200	Print-goods; 9,000 spindles.
Floyd Kransky	12	50	Thread-mill.
Aldrich & Milner	21	200	Fancy cassimeres; 12 sets of cards.

These mills all lie between the mouth and Almyville, a distance of 4 or 5 miles. Above, at Sterling, there is a small mill manufacturing colored umbrella cloth and cotton goods; there are also said to be a few saw-mills above Oneco, but no important powers are in operation.

There are several falls on the stream not in use. The lowest of these in order is below Canada City, near the mouth, amounts to 9 feet, and is owned by Mr. Henry Tripp, of Central Village. Judging from the powers at the other mills, this privilege should be reliable for 80 effective horse-power ten months in the year.

Immediately below their mill Messrs. Aldrich & Gray own 17 feet of unimproved fall, equivalent, on the same basis as above, to about 150 horse-power.

At the Almyville stone dam, Messrs. Aldrich, Milner & Gray hold for sale a fine unoccupied privilege. It is close beside the Providence division of the New York and New England railroad, which follows up the valley of the Moosup river nearly to Greene, Rhode Island, and has good building stone and sand close at hand. The dam is of horseshoe shape, 18 feet high, and constructed of stone; the face descends by a series of offsets, or steps. On the right bank the dam abuts against a rock ledge; on the left it is supplemented by a short embankment faced on the sides with stone. It was reported that within a year, during a freshet, water had forced its way across the shore end of this embankment, but that prompt action had prevented serious harm being done. Above the dam is a long narrow pond estimated to contain 100 acres; the owners design raising the dam 3 or 4 feet, and thereby increasing the flowage by 250 or 300 acres.

At Oneco, in the eastern part of the town of Sterling, there is a good privilege, formerly occupied by the Oneco Manufacturing Company, cotton goods, using 18 feet head and 100 horse-power. The dam is of wood, 100 feet long and 12 feet high, and creates a pond of 125 acres.

Five-Mile river rises in the town of Douglas, Massachusetts, runs southerly through the towns of Thompson, Putnam, and Killingly, Connecticut, and empties into the Quinebaug at Danielsonville. Its length by general course is about 19 miles, and its drainage area 77 square miles. Its principal branch is Whitestone—also called Whetstone—brook, which will be separately described.

The valley of Five-Mile river is in general rather wide and flat. The stream itself is 30 or 40 feet wide in its lower course, and runs over a bed covered with stones. It is supplied from reservoirs and has a very steady flow; there are no freshets in it of consequence, it is free from anchor-ice, and surface-ice never goes over the dams, but melts away in the ponds. This stream has been developed to about its full capacity. With one exception, no available unimproved fall below Quaddick reservoir could be learned of, and it is also claimed that the reservoir storage cannot be further increased unless at unreasonably heavy expense.

There are now three principal storage reservoirs in this basin. Wakefield pond lies in the eastern part of the town of Thompson and drains into Quaddick pond, which is immediately below it; the two are estimated to cover 1,500 acres. Quaddick pond can be drawn down 11 feet. Both are natural lakes raised by dams. They are owned, three-quarters by the Attawaugan Company and one-quarter by Sabin L. Sayles. They are filled mainly by the melting snows and rains of spring, and the mills commonly begin to draw upon them in July. Keach's reservoir is of good size, but its area could not be ascertained. It empties by a side stream between Quaddick pond and the Attawaugan Company's upper privilege, and is owned jointly by several of the mills.

Water-privileges on Five-Mile river below Quaddick reservoir (in order from the mouth).

Occupied by—	Fall.	Horse-power utilized.	Remarks.
	Feet.		
Quinebaug grist-mill	12	50-75	Has no separate dam. Obtains 5 feet fall from the tail-race of the Danielsonville Cotton Company, and 7 feet at the Quinebaug Company's dam adjacent on the Quinebaug.
Danielsonville Cotton Company	24½	360	Manufactures cotton sheetings; 17,000 spindles. Stone dam about 110 feet long. Can store the night-flow of the stream about half the year.
S. L. Sayles & Co	19	200	Located at Dayville. Manufacture fancy cassimeres. Ordinarily have sufficient water throughout the year.
....	8-10	....	Small saw-mill.
Attawaugan Company (a)	30	236	Stone dam 25 feet high, 120 feet long.
Do	26	220	Stone dam; 20-acre pond.
Do	12	....	Do.
....	24	....	Owned by Sabin L. Sayles, but unoccupied. Has a good stone dam and long narrow pond, and is less than half a mile from the Attawaugan Company's upper privilege.
....	12	40	In use by twine-mill at outlet of Quaddick reservoir.

a This company manufactures plain cotton goods. One mill weaves, and the other two mills have together 37,000 spindles.

Whitestone brook is a little stream, not over 4 miles long measuring from the reservoir at its head. It runs westerly across the town of Killingly, and drains 19 square miles. The bed is gravelly and rocky; the fall is slight in the middle course, but large toward the mouth, and especially so in the upper waters, where the valley is narrow and hemmed in by high hills. The dams are short and usually built of stone. In the summer of 1882 eleven privileges were in use, the manufacturing at which was confined to cotton goods and fancy cassimeres. The falls were large, ranging in several cases from 20 to 40 feet; there was also one fall of 14 feet occupied by a cotton-mill not running; and one of 38 feet, near the head of the stream, entirely unimproved.

This brook is considered a fair milling stream. Its flow is well sustained, but is not sufficient to carry the mills through the year, and nearly or quite all of them use steam in low water. The reservoirs are all at the head of the stream, and are as follows: Old Killingly pond, the largest, is a natural lake raised by a dam. When drawn down all that is practicable, 15 feet below full-water line, a large amount of water still remains in the natural basin. The pond is fed by springs, but receives very few brooks; it partially fills in spring from rains and melting snows, but has not been full in ten years. If full, this pond alone, it is said, would carry the mills on the brook for three months. It is practicable, and the plan has been discussed, to drain the surplus waters of the upper course of Five-Mile river into this pond. No injury would be done to that river, the reservoir would be filled, and the power of Whitestone brook very much increased.

There are four other reservoirs, known as Edy, Simmons, Middle, and Bog Meadow; they can be drawn down from 8 to 12 feet each, and flow an aggregate area estimated at 255 acres. They are entirely artificial, and have been built at considerable expense.

All of the five reservoirs which have been mentioned drain into a pond just above Ross' mill, the highest on the stream and located nearly at the top of Chestnut hill. They all, with the exception of Old Killingly pond, fill regularly in spring, and the mills commonly begin to draw upon them in May. All are owned by a reservoir company, in which most of the mill-owners on the stream are shareholders.

French river.—This stream, the most important tributary of the Quinebaug, rises in the towns of Leicester and Spencer, Worcester county, Massachusetts. It flows southerly, with an extreme length of 25 or 30 miles, and joins the main river in the town of Thompson, Connecticut. Its drainage basin includes 115 square miles. In the upper waters are numerous artificial storage reservoirs, of which the principal ones are as follows:

1. Chaubunagungamaug lake is a splendid sheet of water lying east of the village of Webster. It has a very irregular outline, measuring 17 miles in circuit, contains 1,300 acres, drains 9 square miles, and can be drawn down 4 feet from full-water line. The aggregate draught upon it in an average year is estimated equivalent to a depth of 10 or 11 feet. This lake is supplied by many springs, and also has three brook feeders.

2. Robinson pond lies in the towns of Oxford and Sutton, and drains into French river some 4 miles above Webster. It is artificial, contains 100 acres, can be drawn down 4 feet, and is controlled by a small mill on the outlet.

3. Sacarap reservoir is artificial, and lies in the town of Oxford. It contains 125 acres, is 27 or 28 feet deep, and can be drawn down the whole depth. It is used for storage purposes alone, and there is rarely any waste of water at the outlet.

4. Charlton or Granite reservoir, artificial, is controlled by Messrs. Buffum and H. N. Slater. It contains 240 acres, will fill twice in the year, or the equivalent of once to an average depth of 16 feet, and drains 7 square miles.

5. Pierpont Meadow pond, in the northern part of the town of Dudley, is artificial, flows 100 acres, and averages, say 5 feet in depth.

6. Platte pond, in Charlton and Oxford, is artificial. Its water-shed embraces 11 square miles, with steep and impervious drainage slopes. This reservoir is 17 feet deep, covers 125 acres, and fills many times in the course of a year.

7. Burncoat pond, in the town of Leicester, 142 acres, can be drawn down 12½ feet from the top of the roll-way. It is owned by the Rochdale Mills.

8. Cedar Meadow pond, in the southwestern part of the town of Leicester, flows 153 acres, and can be drawn down 11 feet. It is owned by the Rochdale Mills. Both Burncoat and Cedar Meadow ponds fill regularly in spring, and the water can be drawn quite thoroughly from their basins. The average depth for their entire surface is probably not more than 6 or 7 feet.

9. Styles' reservoir, artificial, is controlled by an association of mill-owners. It is 26 or 27 feet deep, flows 400 acres, and drains an area of 7 square miles.

Except as stated otherwise, the above reservoirs are owned by the Messrs. Slater, of Webster. In addition to these sources of supply for French river, the Stevens Linen Works, of Webster, control 279 acres of storage, comprised in a series of five reservoirs lying westerly from the village.

In the lower part of its course French river is perhaps 50 feet wide where running freely, with a good current, and shoals at intervals. There is but a small portion of its course below Webster, however, that is not controlled by dams. But one unimproved privilege in that distance was reported; it lies between Mechanicsville and Grosvenordale, includes 15 feet fall, and is owned and held for its own use by the Grosvenordale Company. In this section the immediate valley of the stream is rather narrow, though it widens out occasionally and incloses meadows, through which the river flows between banks from 5 to 8 feet high. The bed of the stream is generally gravel, and its waters are clear and of good quality; they have no injurious action upon iron surfaces, but, if allowed to stand, show a kind of gelatinous deposit which is supposed to be due to vegetable matter.

Power is used on the lower course of this stream as shown in the following table:

Water-privileges on French river below the village of Webster (in order from the mouth).

Locality.	Occupied by—	Fall.	Horse-power utilized.	Remarks.
		Feet.		
Mechanicsville	Sayles & Washburn	15	200	Pondage estimated at 50 acres. Can run full capacity by water all but one or two days in the year. There is always a surpluswhen the Grosvenordale mill is running. No trouble from backwater or ice. Manufacture fancy cassimeres.
Mechanicsville-Grosvenordale.	Grosvenordale Company	15	....	Fall unimproved and held for company's own use.
Grosvenordale	......do (*a*)	12	180	Cotton goods; 20,000 spindles. Stone dam; roll-way 116 feet long.
Do	......do (*a*)	12	180	Cotton goods; 11,000 spindles—harder driving than previous mill. Stone dam.
North Grosvenordale	......do	26½	400	Two splendid brick mills for the manufacture of cotton goods; 65,000 spindles. Stone dam; roll-way 104 feet long, with a spill-way of equal length for high water. Pond of 80 acres, which serves as reservoir for the three privileges. Can realize 400 horse-power from water practically all the time; 300 horse-power or more of steam also in use.
Wilson's station	O. F. Chase	12	45–50	Manufactures cassimeres.
Perry's station	Dudley Woolen Mills, Josiah Perry proprietor.	10	75	Fancy cassimeres; 6 sets of cards. Curving stone dam.
Below the village of Webster	John Chase & Sons	10½	....	Fancy cassimeres. The pondage at these upper privileges is small, and the mills are dependent upon the running of those at Webster.

a Both mills can run at full capacity by water all the year. No hinderance from backwater or ice. Small ponds here, but at North Grosvenordale there is a large pond which for five months in the year controls the flow of the stream.

Webster is a large manufacturing village, with extensive mills, using power from three different streams. On the main French river, at what is known as the South village, the Messrs. Slater (Slater Woolen Company) manufacture woolen goods, using 17 feet fall, 315 horse-power of water, and say 175 of steam. At the North village, also on French river, they manufacture cotton goods, employing 18 feet fall, and an average of 200 horse-power of water and 350 of steam.

At the East village, on the outlet of lake Chaubunagungamaug, the same company has dyeing and finishing works, with from 24 to 28 feet fall and utilizing 100 horse-power, which can always be realized from the supply furnished by the lake.

The Stevens Linen Works are located upon a small stream supplied by five reservoirs, previously mentioned. These have a combined flowage of 279 acres, and are in the main artificial, only one having been a natural pond. They generally fill in the spring, but are soon drawn down, and furnish enough water for running the various wheels at full capacity only about three months in the year. Steam is used at the bleachery a part of the time, and at the main mill constantly. At the former a 75 horse-power turbine is run under 12 feet head. At the main mill there are two falls. The upper has a 40-foot breast-wheel, with buckets 15 feet wide, and is estimated at 150 horse-power; the lower has a 20-foot breast-wheel, with buckets 15 feet wide, and is roughly estimated at 50 horse-power. The Stevens Linen Works manufacture linen towelings, employ 400 hands, and use 800 tons of stock per year. The principal mill is a handsome structure of stone, 200 by 70 feet in plan, five stories high, and with two large L's.

Passing above Webster, French river continues to be used at short intervals for power, but its size is reduced and the mills are comparatively small.

MINOR TRIBUTARIES OF THE QUINEBAUG.

Mashamoquet brook runs southerly and then southeasterly through the town of Pomfret, Connecticut, joining the Quinebaug a mile or so above Williamsville. It drains 30 square miles, and is used for power by several small saw- and grist-mills. At Pomfret Landing, Binn's 2-run grist mill has 20 feet fall, 55 horse-power of wheels, and is short of water during July and August. The brook is about 40 feet wide between banks in its lower course, has a rapid descent, and is very unsteady, coming up and falling again quickly after rains. The common freshet-rise at Pomfret Landing, which is near the mouth, is about 6 feet, but after a heavy winter or spring rain a rise of 15 feet has been known, widely overflowing the valley.

There is undeveloped fall on the stream, and opportunities exist for considerable storage. The people living near are said to be anxious to have the power improved, and to be willing to assist in any enterprise looking to that end. Six miles above Pomfret Landing, at what is known as the Nightingale privilege, it is claimed that, by building a dam 250 feet long, 20 feet of water could be stored, flowing a surface of 600 acres. This privilege is said to be owned by Mr. Joshua Angell, living near by. It was reported, also, that at a point 2 miles above Pomfret Landing there is an unoccupied privilege, with dam already built, where by putting in gates a considerable flowage can be commanded.

For ten months in an average year a discharge from this stream at its mouth of from 12 to 15 cubic feet per second can probably be relied upon under the present conditions.

Alexander's pond contains, by map measurement, 216 acres. It lies a little way east of the Quinebaug and north of Williamsville. In winter Five-Mile river sends its surplus waters into this pond, but its only outlet is by a small stream emptying just below the Williamsville mill. It can be drawn down 4½ feet, and furnishes power most of the year to O. S. Arnold's bobbin-shop, using 32 feet fall and 35 horse-power.

Little river, or *Muddy brook*, comes down through the town of Woodstock, Connecticut, and empties into the Quinebaug near Putnam. It is stated to have a rapid fall and to be used for power at several points by small twine- and cotton-mills. For 1 mile above the mouth the fall on this stream, including two privileges of 16 feet each, is owned by Mr. George Morse, of Putnam. Immediately above there was formerly a weaving-mill using 18 or 19 feet fall; Woodstock pond, measuring 86 acres on an old state map, but represented to me as now flowing over 200 acres, serves as a reservoir for this privilege.

THE YANTIC RIVER.

Formed by small streams rising in the towns of Lebanon and Colchester, Connecticut, the Yantic flows southeasterly, and at Norwich joins the Shetucket to make up the Thames. It drains an area of 96 square miles, composed of a hilly country, well timbered away from the immediate valley and especially in the upper waters. This district is well supplied with springs, and the river also receives aid from several reservoirs; nevertheless its volume sinks quite low in the dry season, and the mills generally rely upon steam for assistance then. The Yantic rises rapidly after heavy rains, and is described as an "angry little stream" at such times. Considerable running ice passes down its course on the breaking up of winter, and slight hinderances are suffered at times from anchor-ice and backwater; trouble from these causes is not sufficient, though, to cause any stoppage of the mills, except in rare instances. The stream is quite variable in width, but in the lower course, where running freely, does not usually measure more than 50 or 75 feet across.

Of the reservoirs, Gardner's lake, situated on the boundary between the towns of Salem, Montville, and Bozrah, is the largest. It flows 816 acres, and drains an estimated surface of 3,268 acres; it is a natural pond raised by an embankment, can be drawn down 7 feet, and fills regularly. This reservoir is owned by the Falls Company, of Norwich.

The Bozrahville Company controls two reservoirs in the western part of the town of Lebanon. Neither their names nor size could be learned with certainty, but they are probably the sheets of water represented on the maps as Williams and Kent ponds. By measurement upon a county map of 1868, Williams pond contains 330 acres, and Kent pond 83 acres; the latter lies below Williams pond, a short outlet joining them.

The Hayward Rubber Company owns a reservoir in the southern part of the town of Lebanon, known as Cedar Swamp reservoir; it is fed mainly by springs, covers 145 acres, and can be drawn down 10 feet.

It is stated that the country drained by the Yantic is very favorable to the construction of reservoirs, and that the capacity in that respect might be materially increased. There are several small streams, of which Deep brook is one, that would furnish a good supply of water and might be thus improved.

In the 9 miles from Bozrahville to the mouth, including the more important part of the river's course, the fall is almost entirely taken up. It appears to be mainly concentrated in two sections. From a mile above Bozrahville down to Fitchville it is rapid, amounting to 104 feet at four privileges. For 3 miles above the upper end of this section the fall is slight; it is also slight below it to the vicinity of the mouth, amounting to only 30 feet at three privileges, but at Norwich the descent is again large.

Principal water-privileges on the Yantic river (in order from the mouth).

Locality.	Occupied by—	Fall.	Horse-power utilized.	Remarks.
		Feet.		
Norwich	Falls Company	53	850	Manufactures tickings and cheviots; 20,000 spindles. The river here falls precipitously through a narrow rocky gorge, at the head of which is a curved stone dam from 160 to 170 feet long. Water is carried from the pond in a race and used in two levels. At the upper level 28 feet fall and about 450 horse-power are used; at the lower level 25 feet fall and 400 horse-power. These amounts can be realized about nine months in the year; the rest of the time the supply of water is deficient. Tide-water sets back to this privilege, and rises about 3 feet on the wheels.
Do	Falls Company (upper privilege)	17	....	Power leased by Falls Company to Norwich Pistol Company and Allen Spool Company, using, respectively, 15 and 17 feet fall from a common race. Pond large, but shallow. Stone dam, 21 feet high, 20 feet wide at base, inclined coping stones, 7 feet long; face of dam batters 4½ inches to 1 foot.
Norwich Town	Norwich Woolen Company	7	100	Manufactures blankets and repellents; 12 sets of cards.
Bean Hill	Clinton Mills Company	9	85	Repellents; 11 sets of cards. Stone and wood dam. Can run from seven to ten months at full capacity by water, but uses steam in low water.
Yantic	Yantic Woolen Company	14	....	Manufactures flannels; 10 sets of cards. Uses two 42-inch Swain and one 36-inch Hunt wheels. Can run full capacity nine months by water, and estimates that power never falls below 50 horse-power. Framed dam, 70 feet roll-way. Small pond.
Fitchville	Fitchville Manufacturing Company.	24	300	Cotton goods; 18,000 spindles. Receives the benefit of Gardner's Lake outlet, which empties shortly above here. Pondage about 90 acres above dam. Latter is a stone and timber structure, 95 feet roll-way. In low water of August, 1882, about three-quarters of the capacity of the wheels was being realized. Can usually run nine or ten months in the year at full capacity; in the dry season of 1881 the supply in the reservoirs failed, and for a time there was no water here worth mentioning.
....	Bailey	....	....	Saw-mill.
Bozrahville	Bozrahville Company	20	....	Privilege unoccupied, but held for company's use. Already improved in part by a dam giving from 10 to 12 feet fall.
Do	......do	30	125	Manufactures cotton goods; 7,000 spindles. Can commonly run eleven months in the year at full capacity, but uses steam in low water. River is rocky here, and dam rests on natural ledge. Small pondage at dam, but company controls two reservoirs previously described, the larger of which will maintain the supply at this privilege six weeks under ordinary circumstances, and the smaller two weeks.
Do	Hayward Rubber Company	30	175	Grinding-mill.

Above the Hayward company is the Yantic Paper Company, and there are possibly one or two saw- and grist-mills still higher up stream. There is fall at the various reservoir outlets which is said to be used, in some cases at least, by small saw- and grist-mills; but being regularly drawn down, the reservoirs can furnish power for only a part of the year, and the amount on any one outlet would be small.

Utilized power on tributaries of the Thames river.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	H. P.	H. P.	
Thames river	Long Island sound	Connecticut	New London	....	....	....	....	....	
Shetucket river	Thames	do	do	Cotton	1	14½–17	1,600–1,700	700	Norwich.
Do	do	do	do	Bleaching and calendering works.	1				
Do	do	do	do	Paper	2				
Do	do	do	do	Flour and grist	1				
Do	do	do	do	Cotton	3	61	2,580	250	
Sundry small tributaries	Shetucket	do	do	Woolen	3	63	265	150	
Do	do	do	do	Worsted	1	28	10	40	
Do	do	do	do	Pulp	1	12	75	....	
Do	do	do	do	Paper	1	21	104	....	
Do	do	do	do	Fire-arms	1	40	10	10	
Do	do	do	do	Furniture	1	18	18	....	
Do	do	do	do	Saw	3	44	34	....	
Do	do	do	do	Flour and grist	1	12	50	....	
Do	do	do	Windham	Woolen	2	24	143	....	
Do	do	do	do	Paper	1	14	63	....	
Do	do	do	do	Cooperage	1	10	30	20	
Do	do	do	do	Fertilizers	1	26	15	....	
Do	do	do	do	Flour and grist	5	82	97	30	
Do	do	do	do	Saw	4	50	110	....	
Do	do	do	do	Machinery	1	55	80	....	
Do	do	do	do	Wooden types	1	30	35	....	
Willimantic river and tributaries	do	do	do	Cotton	5	87½	1,750	850	Willimantic. The Linen company has three mills here included, while a fourth is operated by steam alone.
Do	do	do	do	Sashes, doors, and blinds; wood turning and carving.	1	....	....	....	Rents power from Linen company.
Do	do	do	Tolland	Cotton	6	123	418	275	
Do	do	do	do	Woolen	13	305	744	460	
Do	do	do	do	Shoddy	8	44	15+	....	
Do	do	do	do	Upholstering materials.	1	26	15	....	
Do	do	do	do	Worsted	1	25	100	75	
Do	do	do	do	Hosiery	1	10	30	15	
Do	do	do	do	Silk	3	34	21+	....	
Do	do	do	do	Flour and grist	7	146½	155	....	
Do	do	do	do	Saw	12	143+	226	....	
Do	do	do	do	Ammunition	1	7	10	....	
Do	do	do	do	Blacksmithing	3	39	20	....	
Do	do	do	do	Boot and shoe findings.	1	40	12	....	
Do	do	do	do	Machinery	3	36+	50	15	
Do	do	do	do	Wood turning and carving.	1	36	40	....	
Do	do	do	do	Wheelwrighting	1	....	2	....	
Do	do	do	do	Carriage spokes	1	14	....		
Do	do	do	do	Wool extract	1	18	....	....	
Do	do	do	do	Wooden packing-boxes	2	15	52	....	
Do	do	do	do	Fire-arms	1	29	6	....	
Do	do	do	do	Musical instruments, organs.	1	10	35	....	
Do	do	do	do	Tools	1	7	4	....	
Natchaug river and tributaries	do	do	Windham	Cotton	2	22	75	....	
Do	do	do	do	Woolen	2	30	38	....	
Do	do	do	do	Silk	1	20	20	....	
Do	do	do	do	Flour and grist	8	95	179	....	
Do	do	do	do	Saw	13	154+	229	5	
Do	do	do	do	Paper	1	22	180	....	
Do	do	do	do	Wood-pulp	1	17	75	....	
Do	do	do	do	Agricultural implements.	1	10	33	....	
Do	do	do	do	Carriages and wagons.	1	16	50	25	
Do	do	do	do	Wheelwrighting	2	27	16	....	
Do	do	do	do	Wood turning and carving.	2	17	23	....	

Utilized power on tributaries of the Thames river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
Natchaug river and tributaries	Shetucket	Connecticut	Windham	Fertilizers	1	10	24		
Do	do	do	do	Cordage and twine	1	11	15		
Do	do	do	do	Tin, copper, etc	1	11	65		
Do	do	do	Tolland	Cotton	1	14	60		
Do	do	do	do	Woolen	1	20	50	50	
Do	do	do	do	Silk	6	63+	102	22	
Do	do	do	do	Saw	4	63	57		
Do	do	do	do	Wooden packing-boxes	1	12	12		
Do	do	do	do	Blacksmithing	1	10	4		
Do	do	do	do	Wheelwrighting	1	5	5		
Quinebaug river	do	do	Windham	Cotton	8	112	3,440	1,035	
Do	do	do	do	Woolen	1		340		Fall included above.
Do	do	do	do	do	1	9½	100		
Do	do	Massachusetts	Worcester	Cotton	5	89	1,110		Three mills at Southbridge and two in Sturbridge.
Do	do	do	do	Print works	1	14½	285		
Do	do	do	do	Woolen	2	40	475		Southbridge.
Do	do	do	do	Bagging, etc	1	12	138		
Do	do	do	do	Flour and grist	1				
Do	do	do	do	do	2	22	60		
Do	do	do	do	do	1	13	152		
Do	do	do	do	Paper	1				
Do	do	do	do	Spectacles and eye-glasses.	1	7½	35		
Do	do	do	do	Cutlery and edge-tools.	1	12	81		
Do	do	do	do	Saw	1	7	40		
Do	do	do	do	Machinery	1	6	25		
Do	do	do	do	Marble and stone work	1	9	20		
Do	do	do	do	Carriage and wagon materials.	1	9	20		
Do	do	do	Hampden	Flour and grist	2	20	52		
Do	do	do	do	Saw	2	16	81		
French river and tributaries	Quinebaug	Connecticut	Windham	Cotton	4	50	760	450	Grosvenordale Company.
Do	do	do	do	Woolen	2	27	250		
Do	do	Massachusetts	Worcester	Cotton	5	84	461	390	
Do	do	do	do	Woolen	10	157	1,265	175	
Do	do	do	do	Shoddy	2	12+	105	30	
Do	do	do	do	Linen	1	72	275	(?)	
Do	do	do	do	Flour and grist	6	98	158		
Do	do	do	do	Saw	6	88	128		
Do	do	do	do	Wooden packing-boxes	4	43+	60		
Do	do	do	do	Wire	1	17	20	15	
Do	do	do	do	Cutlery and edge-tools	3	32	103		
All other tributaries	do	Connecticut	New London	Cotton	4				
Do	do	do	do	Woolen	1	75	868		
Do	do	do	do	Flour and grist	1				
Do	do	do	Tolland	Saw	2	34	40		
Do	do	do	Windham	Cotton	29	625	2,648	1,106	
Do	do	do	do	Woolen	3	70	331	300	
Do	do	do	do	Twine, etc	1	9	100		
Do	do	do	do	Upholstering materials.	1	12	60		
Do	do	do	do	Flour and grist	18	272	640	40	
Do	do	do	do	Saw	27	311+	692+		
Do	do	do	do	Sashes, doors, and blinds.	1	8	8		
Do	do	do	do	Wheelwrighting	3	30+	59		
Do	do	do	do	Carriages and wagons.	1	4	35		
Do	do	do	do	Machinery	3	15+	20		
Do	do	do	do	Saddlery hardware	1		5		
Do	do	do	do	Fertilizers	1	13	32		
Do	do	do	do	Drugs and chemicals	2	20	20		
Do	do	Rhode Island	Providence	Saw	2	30	37		
Do	do	do	Kent	do	3	47	88		
Do	do	Massachusetts	Worcester	Woolen	2	31	53	55	
Do	do	do	do	Bagging, etc	1	12	360	300	

Utilized power on tributaries of the Thames river—Continued.

Stream.	Tributary to what.	State.	County.	Kind of mill or manufacture.	Number of mills.	Total fall utilized.	Total water-power utilized.	Auxiliary steam-power.	Remarks.
						Feet.	*H. P.*	*H. P.*	
All other tributaries	Quinebaug	Massachusetts	Worcester	Buttons	1	7½	8	......	
Do	do	do	do	Spectacles and eye-glasses.	1	9	5	......	
Do	do	do	do	Flour and grist.	2	29	49	......	
Do	do	do	do	Saw	5	38+	87	......	
Do	do	do	do	Sashes, doors, and blinds.	1	12½	25	......	
Do	do	do	do	Cutlery and edge-tools.	3	15+	11	......	
Do	do	do	Hampden	Woolen	3	....	115	150	
Do	do	do	do	Saw	2	21	36	......	
Do	do	do	do	Brick- and tile-works	1	42	45	......	
Yantic river	Thames	Connecticut	New London	Cotton	3	107	1,275	400	
Do	do	do	do	Woolen	3	30	315	210	
Do	do	do	do	Vulcanized rubber	1	30	175	......	
Do	do	do	do	Paper	1	24	105	......	
Do	do	do	do	Flour, grist, and saw	1	9	60	......	
Do	do	do	do	Fire-arms	1	} 17	95	......	
Do	do	do	do	Spools	1				
Tributaries	Yantic	do	do	Flour and grist	2	28	34	......	
Do	do	do	do	Saw	5	50	112	......	
Do	do	do	do	Wheelwrighting	1	7	9	......	
Sundry small tributaries	Thames	do	do	Cotton	6	139	480	245	
Do	do	do	do	Woolen	7	121	275	70	
Do	do	do	do	Paper	6	129	280	60	
Do	do	do	do	Dye woods, dye-stuffs, and extracts.	1	14	50	40	
Do	do	do	do	Flour and grist	10	208	224	......	
Do	do	do	do	Saw	8	117	151	......	
Do	do	do	do	Wheelwrighting	1	7	5	......	

II.—THE CONNECTICUT RIVER AND TRIBUTARIES.

THE CONNECTICUT RIVER.

This stream, the most important one reaching Long Island sound, rises in the Connecticut lakes, in the extreme northern part of New Hampshire. It flows in a general southerly direction, forms the boundary between New Hampshire and Vermont, and, passing across the states of Massachusetts and Connecticut, empties toward the eastern end of the sound. Its length by general course is about 300 miles; following the windings as closely as possible on state maps, the length measures about 375 miles, and probably this is somewhat under the true distance. The drainage basin includes 10,924 square miles. In shape it is long and narrow, ranging from 40 to 50 miles in width in the upper course, and not much exceeding 60 miles in Massachusetts, where it is widest. In the north the section drained by the river is hemmed in by the White mountains of New Hampshire and the Green mountains of Vermont; to the southward, through Massachusetts and Connecticut, the water-shed lines are continued by ranges of high rocky hills. The character of the country thus included has been sufficiently described in the general remarks upon this part of New England. The impermeable rock which underlies the surface, the sands, gravels, and clays of the drift soil, all favor the formation of springs, which, together with numerous lakes and storage reservoirs, render the various minor streams, and in consequence the main river, steady and well sustained in droughts.

For the first 200 miles from its source the river contains numerous shoals and rapids and occasional abrupt pitches; but below Bellows Falls the general descent becomes much slower, and is broken by falls or important rapids at only three points—Turner's Falls and Holyoke, Massachusetts, and above Windsor Locks, Connecticut. At many localities along the upper course the high hills which inclose the valley approach close to the stream, and give rise to scenery which is beautiful though rather rugged; farther south, and especially in the vicinity of